The Real Option Premium in Japanese Land Prices [*]

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Abstract

The present paper examines the empirical implications of the real option pricing model developed in Quigg (1993) using Japanese data. We find the option to wait to develop land, embedded in Tokyo land prices, is slightly lower in the so-called "bubble-economy" period of the late 1980s. The implied volatility estimate is lower in the "post-bubble" period of the early 1990s. This is consistent with Quigg (1995) and Grenadier (1995) where fluctuations in the likelihood of exercising the "option to develop" is a source of building cycles.

Key Words: Real Option, Land Prices, Japanese Economy

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1 INTRODUCTION

For the past fifty years, Japanese real estate prices have increased by at least twelvefold. [1] Since land prices have continued to increase year after year, real estate has been perceived as a good investment in Japan, particularly in Tokyo. This phenomenon in real estate investment is referred to as tochi-shinwa, implying that land prices would never decline in the long run (Ito, 1992). [2] This perception fitted especially well with people's intuition as they saw a sharp appreciation of land prices in the second half of the 1980s, a period to which we refer to now as the "bubble-economy" period. This perception, however, proved wrong as Tokyo residential land prices peaked around 1988, remained relatively stagnant until 1991, and then began to decline dramatically around 1992 for the first time in Japan's post-war history. Figure 1 shows how the Tokyo real estate market behaved during this period. The thick straight line represents the Land Price Index for Tokyo residential land properties disclosed by the National Land Agency (Kokudocho). The index doubled in value around 1987. The dotted line and the straight line with square markers in Figure 1 represent the housing starts and land transactions, respectively, in Tokyo. Both measures show that the real estate market was most active around 1986-88, and became stagnant in the 1990s.

This recent history of the Japanese real estate market enables us to test the predictions of the real option pricing model in two very different investment environments. We investigate the empirical implications of option-based real estate valuation in a period when the Tokyo real estate market was the most active in the late 1980s and in a period when the market became increasingly stagnant in the early 1990s. Profit-maximizing real estate developers are willing to commit to development when the payoff is rewarding, and unwilling under a less profitable environment. This market-timing behavior of developers should affect the overall real estate development activity in the economy. [3]

[1] Stone and Ziemba (1993) provide an overview of the economics of Japanese land prices.

[2] An exception is when land prices dropped in 1975 during the recession after the first oil shock.

[3] One could argue that simply selling the vacant lot, or developing the lot immediately and then waiting to sell (develop-and-hold) are alternative strategies to waiting to develop (wait-to-develop real option). The wait-to-develop option, we argue, is relevant in the Japanese context.

Option pricing technology is applicable not only to the valuation of financial assets but also to that of real assets. Dixit and Pindyck (1994), and Trigeorgis (1996) provide comprehensive coverage of real option theory. Theoretical real option pricing models have been developed in various contexts; Brennan and Schwartz (1985) value the option to temporarily shut down and restart in natural resource investment decisions; McDonald and Siegel (1986) develop a model to value the option to defer investments; Dixit (1989) values entry and exit flexibility for capital investments; Gibson and Schwartz (1990) value oil contingent claims; Pindyck (1993) deals with investment decisions under cost uncertainty; Trigeorgis (1993) values corporate investment projects as a bundle of multiple real options with interactions among them; Kulatilaka (1995) values models of general operating flexibility as real options; Abel, Dixit, Eberly and Pindyck (1996) value options to expand or contract and their effect on the firm's incentives to invest; among others.

Several papers have applied real option models in the context of real estate. Titman (1985) provides the basic framework and intuition behind the real option pricing model that is tested in this paper. In his two-dated, binomial model, a plot of vacant land is viewed as an option. The owner chooses the timing to develop so as to obtain a higher payoff from the developed property. Development is required to exploit the potential of the vacant land but this also involves development costs. The development cost is at least partially irreversible. Landowners would be better off if they can wait and see how the payoff from developed property changes. This structure closely resembles that of a call option on financial assets, say, a stock, if we view the undeveloped land as the option, the developed property as the

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In Japan, a building is considered an asset which is independent from the site and is priced and taxed accordingly. Since the second half of 1980s, the capital gains tax rates on recently acquired land has substantially increased relative to rates on buildings. Developers would find it in their interest to sell the newly developed property as soon as possible to take advantage of the capital gains tax differential between land and buildings. Thus selling a plot of vacant land has been in general an unpreferrable alternative to take.

In addition, the economic life of a building in Japan tends to be shorter than it ought to be from a functional point of view. Due to the Japanese preference for “new” houses, Japanese houses are rebuilt on an average every 20-24 years, and houses with ages of 10-15 years are often priced lower in the market because the buyers would eliminate the old building and redevelop the sites. Developers are thus induced to sell the developed property as soon as possible since the economic value of the building will decline dramatically, thus making the “develop-and-hold” strategy less feasible.

underlying asset, and the development cost as the exercise price. The real option in this case, however, does not have a maturity date. Selling a plot of vacant land is to forego the value of this real option to wait, hence a rational owner would expect the option value to wait be included in the transaction price. The model then predicts that the market price of vacant land is higher than that of developed property, net of development costs. Williams (1991) extended the model in a continuous-time context and derived a solution for an optimal stopping problem assuming both development costs and the net cash flow from property follow stochastic processes. The option to "redevelop" the property given functional obsolescence over time is analyzed by Cappoza and Sick (1991) and Williams (1997). Other recent papers investigate the relationship between option value and exercise policy. Quigg (1995) raises a qualitative argument that the real option would cause building booms. Grenadier (1995) derives a rational explanation for building cycles. Grenadier (1996), derived the option value employing a game-theoretic approach and analyzed the market conditions that affect investment behavior.

In contrast to the wide array of theoretical research, there is a dearth of empirical research on real options. Recent empirical work includes a study of option values for offshore petroleum leases by Paddock, Siegel, and Smith (1988), real options in commercial real estate development and its exercise behavior by Holland, Ott, and Riddiough (1995), and Quigg's (1993) investigation of the option to develop urban land in the United States. Closely related to the work of Williams (1991), Quigg (1993) examined 2,700 land transactions in Seattle from 1976 to 1979 by using a model where both the underlying asset and exercise price follow stochastic processes. The resulting premia, ranging from about 2% to 30%, were obtained as the ratio of the option-based value less the intrinsic value ("time-value" of the option) to the option-based value.

We investigate whether such findings in the US can be extended to another market, in particular the Tokyo residential real estate market. The Tokyo market provides us with a unique opportunity to test the robustness of the prediction of the real option in countries other than the U.S. Using data of 754 real estate transactions in suburban Tokyo, we measure the real option premium of vacant land prices as well as the implied volatility of developed real estate prices. This study also includes several variables that are specifically important in determining Tokyo land prices. For Tokyo, we find that, the implied volatility estimate is higher and the average option premium to wait for development is slightly lower during the period characterized by a rise in prices in the "bubble" sample period of 1986-88 than in the "post-bubble" sample period of 1991-93. This finding is consistent with Quigg's (1995) hypothesis that a higher likelihood of exercising the real option induces landowners to develop their properties, resulting in a building boom.

2 THE MODEL

2.1 Model settings

The model is adapted from Quigg (1993). The price of developed property at time t, P_t, is the sum of both the land price and building price, and is assumed to take the following form

$$P_t = q_1^{\dagger} q_2^{\hat{u}} \text{ę} \qquad (1)$$

where q_1 is the area of the lot (land), † is the price elasticity of land scale, q_2 is the floor area of the building, û is the price elasticity of building scale, and ę is a function of various attributes of the property, including variables that allow for both time-dependent and stochastic changes. The specific functional form used for estimation is described in Section 4. The development cost at time t, or construction cost of the building, X_t, is expressed as

$$X_t = f + q_2^{\text{ç}} x_{1t} \qquad (2)$$

where f is fixed costs, q_2 is the floor area (square meters) of the building, ç is the cost elasticity of the building scale, and x_{1t} is the development cost per minimum unit floor area of the building. Assuming ç > 1, the development cost per unit floor area increases as the building size increases. [4]

[4] This is reasonable if we assume, for example, that larger houses tend to use higher quality (costly) material or equipment.

The price of the developed property, P, follows at any point in time a geometric Brownian motion with drift

$$\frac{dP}{P} = (ã_P \; Ä \; x_2)dt + õ_P dB_P \tag{3}$$

where $ã_P$ is a constant drift rate, x_2 is the payout ratio to the developed property, $õ_P$ denotes the constant rate of standard deviation of the return of P, and dB_P represents an increment of a standard Brownian motion. The payout ratio, x_2, typically includes the net rent revenue of the building. [5] We assume P is proportional to the stochastic change variable in è in equation (1).

The development cost, X, is also assumed to follow, at any point in time, a diffusion process

$$\frac{dX}{X} = ã_X dt + õ_X dB_X \tag{4}$$

where $ã_X$ is a constant drift rate and $õ_X$ is a constant standard deviation of the return of X. We also assume a constant correlation, $ödt$, between dB_P and dB_X.

In addition, several assumptions are made to formulate a tractable model. We assume that there exists an optimal building size that maximizes the payoff of developers given the environment. We also assume the interest rate, i, the instantaneous riskless rate, is equal for both borrowers and lenders. The investment is assumed irreversible. If the property remains undeveloped, it generates income of $åP$ where the parameter $å$ is assumed to be constant. Investors are price takers, meaning that the development decision of any particular landowner is not expected to affect the market price of real estate. Lastly, we assume that the market is complete with respect to the risks in equations (3) and (4) so that risk-neutral valuation is possible.

2.2 Valuation equation

Based on the assumptions above, we evaluate the exclusive right of landowners to develop their vacant land properties as a real option. What we model here is in fact the real option

[5] This “rate-of-return shortfall” represents the convenience yield of holding the underlying asset rather than the real option.

of real estate developers. These developers typically hold vacant properties as inventory, wait for the timing of development, and develop when the favorable environment prevails.[6] Since they sell off the property immediately after completing construction, they would not face the uncertainty of developed property prices after construction which is a problem raised in Quigg (1995). Given this scenario, we assume the developer is less concerned with the redevelopment option in Williams (1997) or the option for sequential development in Trigeorgis (1993) or Kulatilaka (1995). Since P fluctuates over time, real estate developers would find that the development of vacant properties effectively means foregoing the upside price potential thereafter. By launching the development project and selling the developed property immediately, they obtain the payoff of $P - X$. Downside risk is limited since the developers can postpone the development under an unfavorable market environment, while earning the income of δP. They can develop the property at any time they wish. This enables the developer to exploit the asymmetric payoff scheme as in an American call option on a dividend-paying underlying asset; the developed property is the underlying asset and the development cost is the exercise price. [7] It is at the discretion of the owners of the vacant property to decide whether they should develop the vacant property or not.

To derive the valuation equation, we first replace the drift terms in equations (3) and (4) with $\mu_P \equiv (\alpha_P - x_2) - \lambda_P \sigma_P$ and $\mu_X \equiv \alpha_X - \lambda_X \sigma_X$, where λ_P and λ_X are the constant excess mean returns per unit of standard deviation. The parameters μ_P and μ_X are the certainty equivalent drift rates as in Kulatilaka (1995). [8] Applying Ito's lemma, and given that $E[dV] = (iV - \delta P)dt$, the value of vacant land, $V(P; X)$, is expressed as the solution to

$$0 = \frac{1}{2}\sigma_P^2 P^2 V_{PP} + \sigma_{PX} P X V_{PX} + \frac{1}{2}\sigma_X^2 X^2 V_{XX} + \mu_P P V_P + \mu_X X V_X - iV + \delta P. \qquad (5)$$

To derive a solution we employ a variable-reduction technique by defining the ratio of P to

[6] This is consistent with the fact that our data consists mostly of houses from these, typically small-scaled, real estate developers.

[7] The variable P should be determined by the "best possible" use of the site. Of course it allows the potential conversion from one usage to another, such as a conversion from residentials to commercials. But in the case of properties analyzed here most properties are located in areas with the most strict zoning regulation, not allowing for such conversion.

[8] This replacement is based on the result of Cox, Ingersoll, and Ross (1985) that the risk-neutral valuation is possible when no twin security is available in the market by using certainty equivalent cash flows.

X as z,

$$0 = \frac{1}{2}\omega^2 z^2 W'' + (\delta_P - \delta_X) z W' + (\delta_X - i) W + \alpha z \tag{6}$$

where $z \equiv P/X$, $W(z) = V(P;X)/X$, and $\omega^2 = \sigma_P^2 - 2\rho\sigma_P\sigma_X + \sigma_X^2$.

Equation (6) has a trial solution of $W(z) = Az^j + k(z)$. [9] A set of boundary conditions are needed to solve the equation. [10] Since this real option does not have a maturity date, we will assume an optimal ratio of P to X, denoted as z^*, at which investors optimally exercise the real option.

Given this hurdle ratio, z^*, the solution is then

$$V(P;X) = X\left[Az^j + k(z)\right] \tag{7}$$

where $A = [z^* - 1 - k(z^*)]\,(z^*)^{-j}$, $z^* = j(i - \delta_P)/[(j-1)(i - \delta_P - \alpha)]$, $k(z) = \alpha z/(i - \delta_P)$, $z \equiv P/X$, and

$$j = \omega^{-2}\left\{\frac{1}{2}\omega^2 + \delta_X - \delta_P + \left[\omega^2\left(\frac{1}{4}\omega^2 - \delta_P - \delta_X + 2i\right) + (\delta_X - \delta_P)^2\right]^{\frac{1}{2}}\right\}.$$

The intrinsic value, denoted as $V^I(P;X)$, is

$$V^I(P;X) = \frac{\alpha P}{i - \delta_P} \qquad \text{if } z < 1 + k(\hat{z}); \tag{8}$$

$$V^I(P;X) = P - X \qquad \text{if } z \geq 1 + k(\hat{z}). \tag{9}$$

where $\hat{z}$ represents the optimal point of exercise in the absence of uncertainty (intrinsic value). When z is less than $1 + k(\hat{z})$, investors hold their property undeveloped and earn the income, αP. And when z exceeds $1 + k(\hat{z})$, investors develop the property to earn the payoff of $P - X$. In other words, the investor will develop when the price, P, is greater than or equal to the development cost plus (discounted) income flow, αP, from the vacant lot.

[9] Earlier versions of our draft as well as Quigg (1993) treated the particular integral k as a constant in solving equation (6) when k is in fact a function of z; $k(z)$. We thank Michael Brennan for pointing this out.

[10] The first condition sets an absorbing barrier, or $W(0) = 0$. An option should be worthless if the underlying asset has zero value. The second condition is a "value-matching" condition, or $W(z^*) = z^* - 1$. At the optimal point of exercise, the option-based value and intrinsic value should correspond. And the third condition is a "smooth-pasting" condition, or $W'(z^*) = 1$, for the point to be optimal. See Dixit and Pindyck (1994) for discussions on these conditions.

Hence, we will observe investors exercising the option when the P to X ratio, z, is greater than $1 + k(\hat{z})$.

The option value arises here since the landowner has the exclusive right to exploit the potential appreciation of the price of the developed property. At the optimal point of exercise, the landowner would be indifferent between developing and not-developing the property since both provide the same payoff. In other words, the option value arises because the (expected) net rental income from developed property, whose discounted sum is P, is not high enough relative to the development cost, X.

The payoff scheme of this real option with respect to z is graphically illustrated in Figure 2. The payoff resembles that of a financial call option on some underlying asset. For any value of z less than the optimal point, z^*, the price of vacant land with the option to develop (option-based value), V, is greater than that of developed land with equivalent characteristics (intrinsic value), $P - X$, *ceteris paribus*. Thus when vacant land is sold with the option value alive, the option value should be added to the transaction price. At the same time, however, Figure 2 involves two major differences from the payoff scheme of an ordinary financial option. First, the model assumes an optimal point of exercise, z^*, at which the option-based value and the intrinsic value are equivalent. And second, the intrinsic value in the "wait" ($z < 1 + k(\hat{z})$) region grows at a constant rate, reflecting the fact that a plot of vacant land earns the income δP.

The real option premium is defined as $(V - V^I)/V$ and illustrated in Figure 3. The option premium is the greatest when the intrinsic value is at the "kink," and then declines as z increases. At the optimal point of exercise, $z = z^*$, the premium goes to zero; there is no value of waiting, and the landowner is induced to develop the site.

Finally, we will assume the optimal scale of the building is determined through profit maximization. The profit-maximizing building size, q_2^*, is determined by the initial values of P and X, and is the same for both the option-based and intrinsic values for tractability. And q_2^* depends only on P assuming that other parameters are stable over the relevant time horizon. We derive $q_2^{É}$ by maximizing the value of undeveloped property over q_2

$$
\begin{aligned}
\max_{q_2} V(q_2) &= P(q_2)\ Ä\ X(q_2) \\
&= \max_{q_2} q_1^{†} q_2^{û} è Ä\ (f\ + q_2^{ç} x_1) \qquad (10)
\end{aligned}
$$

which yields the solution

$$
q_2^{É} = \left(\frac{ç x_1}{q_1^{†} è û} \right)^{(1=(ûÄ ç))} \qquad \text{if } q_2^{É} < é; \qquad (11)
$$

$$
q_2^{É} = é \qquad \text{if } q_2^{É}\ ï\ é; \qquad (12)
$$

where é is the maximum building size permitted by the zoning regulation. In this paper we assume $q_2^{É} = é$ as a close approximation for our Tokyo residential area. [11]

3 THE DATA

The data used in the present study was kindly provided by Sugiura Real Estate Appraisal (Tokyo, Japan). The data set is a record of real estate transactions collected by a number of real estate appraisers and covers 754 transactions of real estate in Nerima-ku (ward) in Tokyo for 1986-1988 and 1991-1993. For each transaction, the data covers various attributes of the transaction and property including the transaction price of the land in thousand yen, transaction price of the building in thousand yen, transaction price of the land and building together as a package in thousand yen, area of the of lot in square meters (q_1), age of the building (Age) in months, çoor area of the building in square meters (q_2), distance to the nearest train/subway station (Dist) in meters, and width of the road in front of the lot (Road) in meters, maximum allowable ratio of çoor area to the lot area (called youseki-ritsu in Japanese, and denoted as y), the quarter in which the transaction took place, and zoning regulations. [12]

[11] See footnote 14 in Section 3.

[12] In our sample we employ six zones deåned by zoning regulations. The zones are dai-ishu jukyo senyo chiiki (area for individual houses), dai-nishu jukyo senyo chiiki (apartments and condominiums), jukyo chiiki (area for houses but less regulated), kinrin shogyo chiiki (area for stores), shogyo chiiki (commercial use), and junkogyo chiiki (semi-industrial use). The classiåcation is \cumulative" in the sense that commercial or semi-industrial areas allow residential properties to be built. Individual houses can be built in all zones

The data set is first divided into developed and undeveloped properties. For developed properties, we have 161 observations for the "bubble" period of 1986-88 and a sample of 274 observations for the "post-bubble" period of 1991-93. To derive the option value, we need to estimate the hypothetical price of developed property (land plus building) if the currently-vacant plot of land were to be developed. Specifically, the hypothetical P is obtained by using the parameter estimates from a hedonic regression model; the parameter estimates from the regression using the developed property data set are applied to the undeveloped (vacant) property data set to arrive at the hypothetical P. [13] The vacant property data set includes the price of the property as well as the characteristics listed above in the improved property data set such as the distance to the train station and the width of road. The vacant property data set consists of 118 observations for 1986-88 and 201 observations for 1991-93. The sample observations for the improved and vacant property data sets in both subperiods were limited to plots of land which are less than or equal to 200 square meters. [14]

Table 1 provides the descriptive statistics regarding the composition of our sample, sorted by sample period, types of property, and seller-buyer combination. In the 1986-88 sample, the largest fraction, or 33.9%, of vacant land transactions is from individuals to companies, while the largest fraction, 29.2%, of developed land transactions is from companies to individuals. Recall that, in Figure 1, housing starts hit its peak in 1987. This implies that, in this period, vacant land is sold from individual to companies, developed, and sold to individuals again. In contrast, in yhe 1991-93 sample, the largest fraction of both vacant and developed land transactions were between individual at 46.3% and 41.6% respectively.

And finally for the riskfree rate, i, we used the quarterly 10-year-government-bond yield

in the sample. There are kougyou chiiki and kougyou senyo chiiki both of which are industrial use and not included in our sample. This classification system was altered in 1996. Residential areas are now more segmented.

[13] See Section 4 for details.

[14] In a Tokyo suburban area such as Nerima-ku, houses with the sites larger than 200 square meters are very rare. Our data set consists of the properties of less than or equal to 200 square meters.. These sites are likely to be developed to the maximum in order to build reasonably comfortable houses. The average of the ratios of actual floor area to the maximum allowable floor area by regulation in our sample is in fact approximately equal to one. This presents a clear contrast to Quigg (1993), in which few properties in the data set were developed to the maximum.

for the corresponding quarter which ranged from a low of 3.35% to a high of 5.5% in our sample periods.

4 HEDONIC PRICING OF PROPERTY

4.1 Hedonic pricing model

As we are interested in the potential for construction on a parcel of undeveloped land (option), we require an estimate of the price of the developed property (land plus building) if the currently-vacant land were to be developed. As the price of the hypothetical developed property is not observed we must obtain an estimate. To this end, we estimate an hedonic regression equation using a sample of improved properties and their characteristics. The hedonic regression equation for the price of developed property takes the following form [15]

$$\begin{aligned} \ln P_i = \; & \beta_0 + \alpha \ln q_{1i} + \beta_{age} \ln Age_i + \beta_{dist} \ln Dist_i + \beta_{road} \ln Road_i + \beta_y \ln y_i \\ & + \sum_j \gamma_j Q_{ji} + \sum_k \delta_k d_{ki} + \sum_n \theta_n Z_{ni} + \epsilon_i \end{aligned} \tag{13}$$

where q_1 is land area, Age is the building age in months, $Dist$ is the distance to the nearest train station, $Road$ is the width of the road in front of the lot, y denotes youseki-ritsu which is the maximum allowable ratio of the total area of the building to the area of the lot, Q_j is a dummy variable for jth quarter, d_k is a dummy variable for the kth region in Nerima ward, Z_n is a dummy variable for the nth zone, and ϵ is the error term. The regional dummy reflects train stations within Nerima ward. The specification of the hedonic regression differs from that used by Quigg (1993). We, for example, use youseki-ritsu, y, instead of total building area and thus do not obtain an estimate of the building price elasticity as in Quigg (1993). [16] Furthermore, incorporating $Dist$ and $Road$ as important determinants of price in the Tokyo market distinguishes the present hedonic regression model from that estimated by Quigg. [17]

[15] We applied this functional form based on results from the Box-Cox transformation.

[16] This is due to the fact that land is developed to the maximum in Tokyo, a point which is raised in footnote 14.

[17] Most people commute via public transportation in the Tokyo area, hence the distance to the nearest

The hedonic regression equation is estimated using a sample of 161 observations of developed properties for 1986-88, and a sample of 274 observations for 1991-93. The parameter estimates are then used to obtain hypothetical developed property prices using a separate sample of vacant land observations for each subperiod.

4.2 Empirical results

The results of the hedonic regression are reported in Tables 2 and 3. The estimated coefficient for $\ln q_1$, the price elasticity of land scale, is positive and statistically significant and roughly of the same magnitude for both sample periods . The price elasticity of land scale, †, is 0:8233 in the 1986-88 sub-period and 0:8001 in the 1991-93 sub-period. Due to the difference in explanatory variables, we can not directly compare our parameter estimates for the size-related variables ($\ln q_1$ and $\ln y$) with those reported in Quigg (1993). The price elasticity of land scale, †, seems to remain stable over the two sample periods examined. We find $ã_{age}$ to be negative meaning the older the building is, then the lower price of the building, ceteris paribus. The estimates, Ä0:0834 for the 1986-88 sample and Ä0:0747 for the 1991-93 sample, are significantly greater than those estimated in Quigg (1993), which range between Ä0:007 and 0:001. It is consistent with the short economic life of buildings in Japan, a point which is discussed in Section 1. We also find that the more remotely located is the property from a train station, the lower is the price of the building as indicated by the negative coefficients on $\ln Dist$. Also, the larger the width of the road adjacent to the property, the higher the price of the property. The estimates for $ã_y$ are positive in both subperiods, but statistically significant only in the 1991-93 sample. Overall we find similar results for both the 1986-88 and 1991-93 subperiods in terms of the sign and magnitude of the estimated coefficients for q_1, Age, $Dist$, Road, and y.

Also of interest are the quarterly dummy variables. Each dummy variable represents a particular quarter in the year; for example, the variable \Q864" takes the value of one when

train station becomes an important explanatory variable describing the location. The width of the road is important because it determines the allowable height of the building.

the transaction took place in the fourth quarter of 1986, and zero otherwise. Other quarterly dummy variables follow the same rule. The coefficients for the dummy variables are positive for the 1986-88 period indicating a consistent rise in prices [18] Notice the coefficients are consistently negative for the 1991-93 sample.

5 THE OPTION PREMIUM

5.1 Deriving option values

The model option price is determined by using equation (7). We use parameter estimates from the hedonic regression of the developed property sample and substitute the characteristics of the vacant land observations into the estimated equation to obtain the hypothetical value of P (land and building) for vacant land properties. Age, however, is set to zero since a newly built building has an age of zero.

X is determined by assuming that the fixed cost in equation (2), f, is one million yen. Furthermore, the floor area of the building is obtained by assuming that the building is built to the maximum capacity as determined by regulations as in equation (12) which is a reasonable assumption in the Tokyo area. The minimum unit development cost, x_1, is taken from figures reported in the *hoken-kagaku-hyoka-no-tebiki* (insurance appraisal handbook) published by the Marine and Fire Insurance Association of Japan.

The parameter å is set around 0:009 but allowed to vary between 0.003 to 0.03 so that it minimizes the pricing error. The value of õ$_X$ is assumed to be lower than the volatility of market prices of properties and is set at 0.05, and ö is assumed to be zero. The value of ç was assumed to be 0.99; this allows for some economies of scale. The parameter ç should be close to one over the range of building size in our data. In addition, it provided us with the minimum pricing error. Other assumptions include ù$_P$ = ù$_X$ = 0:02. These values are consistent with those applied by Quigg (1993).

[18] The exception is the first quarter of 1988, just after the reinforcement of regulations against the appreciation of land prices. The fact that parameter estimate for Q881 is in fact less than that for Q874 reflects in this.

The option-based value is obtained by first assuming that vacant land prices have option value. That is, the estimated (hypothetical) P for the currently-vacant lot, the estimated X for the vacant property, and the observed vacant land prices are used in equation (7), to derive the implied value of σ_P. The implied σ_P is found by equating the option-based model price of vacant lot, $V(P; X)$, with the actual observed transaction price for the vacant lot. We take the (cross-sectional) average of the estimates of σ_P across the observations as are our implied volatility estimate in Table 4. Then, using the average implied σ_P, and the estimated P and X for the currently-vacant properties we calculate V again using equation (7). This gives us the model-based price for the vacant lots. The intrinsic value is obtained by using equations (8) and (9). The option premium is then simply calculated by subtracting the intrinsic value from the option-based value and dividing by the option-based value.

5.2 Estimated option premium and implied volatility

Our estimates of the real option premium and implied volatility are shown in Table 4. The average premium is 18.0458% for the 1986-88 sample and 18.5242% for the 1991-93 sample. The implied volatilities (standard deviations) are 36.5681% and 18.3835% for the 1986-88 and 1991-93 sample periods respectively.[19] The implied volatility figures are consistent with the volatility estimates for Seattle prices in Quigg (1993). The volatility estimates are, statistically different across the two sample periods at the 5% level.

The estimated real option premium is slightly smaller for the 1986-88 sample period than for 1991-93 period, even though the implied volatility estimate for the former is substantially greater than for the latter. Although the option premium (time value of option) becomes greater if volatility is greater, *ceteris paribus*, it might not be the case when the underlying variable is more likely to reach the optimal point of exercise. Such a case would arise when the underlying asset price is higher, or when a higher volatility increases the likeliness of

[19] The sample consists mostly of properties in residential areas but includes a few observations on the transactions of properties in Shogyo (commercial) or Jun Kogyo (semi-industrial) areas. Even when we exclude these, changes in real option premium are within the standard errors of the estimates and thus our finding is qualitatively unchanged.

reaching the exercise point, as in Grenadier (1995).

To check for the explanatory ability of the option premium, we regressed the observed price of the vacant land, P_V, on both the intrinsic value, I, and the difference between the option value and intrinsic value, Dif. The regressions takes the form

$$P_{V;i} = ã_0 + ã_1 I_i + ã_2 Dif_i + ñ_t \tag{14}$$

where $ñ_t$ is an error term. If the option valuation model developed in Quigg (1993) is correct, then we would expect the constant term, $ã_0$, to be zero, and the coefficients $ã_1$ and $ã_2$ to be one. The results are displayed in Table 5.

We find that both I and Dif have predictive ability but the estimated coefficients were statistically different from one in both samples, except for the estimate of $ã_2$ of 1986-88 sample, when only Dif is the independent variable. The constant term is not statistically different from zero for the 1991-93 sample when both I and Dif are both included as explanatory variables. Although the null is rejected in most cases, it is of importance to note that the option value over and above the intrinsic value (the premium) has significant explanatory power.

6 REAL OPTION PREMIUM AND DEVELOPMENT ACTIVITY

We observe that the estimated option premium in the 1986-88 period is only slightly smaller than in the 1991-93 period, despite the fact the implied volatility estimates are substantially greater in the "bubble" period. This suggests that in the 1986-88 sample period, the real option is more likely to be exercised because of a higher volatility. Thus, in a sense, the pair of estimates, the real option premium and the implied volatility, represent how much better off landowners could be if they wait for a while. The pair of estimates could be an inverse measure of the willingness of a landowner to develop the site immediately. Then the possibility that a plot of land is developed in a given time interval should be related to these two estimates. [20] Given that the price processes of real estate properties in an area are likely to be correlated, when one observes a higher likelihood of option-exercise for a plot of vacant land, the similar situation should prevail among properties in that area, resulting in enhanced development activities there. This is the hypothesis argued in Quigg (1995) and that Holland, Ott, and Riddiough (1995) partially tested. Our ånding provides support for this argument. Figure 1 illustrates that during 1986-88 housing starts in Tokyo hit its peak. It happens that our volatility estimate (and premium) for this sample period implies that the real option was more likely to be exercised than in the post \bubble" period sample of 1991-93. This is consistent with the theoretical prediction of Grenadier (1995) that overbuilding is more likely as volatility increases.

In addition, an analysis of market participants provides additional insight on the issue. The participants in the real estate market can be roughly divided into two groups: individuals and companies. Companies here typically represent real estate developers. Individual landowners can usually exploit the option to develop only through selling their properties to companies due to their technical or ånancial constraints to conduct development as proåt-maximizing activity. Furthermore, when individuals commit to development activity for their own sake, they would be less sensitive to the changes in real option premia as well as volatility since noneconomic factors such as liquidity needs or lifecycle reasons also aãect their decision. On the other hand, companies can exercise and materialize the option to develop on their own and in many cases commit to a purchase of land with a speciåc development plan. These companies typically purchase land, develop, and sell it consecutively. Based on this scenario, one would predict that when the real option to develop is more likely to be exercised, as in the case of 1986-88 period of Tokyo real estate market, there should be a shift of ownership of vacant land from individuals to companies and a shift of ownership of developed properties from companies to individuals. In other words, companies would buy the vacant

[20] Investors exercise their real option rationally when the option premium is zero. However, given that each investor is unique in the preference on houses and faces diãerent development costs due to the diãerence in the bargaining power with contractors, there would be a range, rather than a point, of P which induces development in the market as a whole.

lots from individuals to develop and then sell the newly developed property immediately after construction. In addition, the relative presence of individuals as market participants would decrease (increase) under such environment. The prediction is indeed supported by the descriptive statistics of our sample, shown in Table 1.

7 CONCLUDING REMARKS

The present paper estimated the value of the option to wait for the optimal timing of development of vacant land in Tokyo. The option premium during the post-bubble period is on average 18.5242%. This is slightly higher than the estimated 18.0458% average premium for the late 1980s which is a period characterized by a dramatic rise in land price. Quigg finds that the premium in residential areas (low and high density) in the US ranged from about 2% to 11% during late 1970s. It is interesting to note that the absolute magnitude of the estimates of the option premium for the Tokyo residential area of Nerima ward is substantially larger than for the US. Hence a part of the difference in residential land prices between the US and Japan could be due to the difference in the option premium to wait embedded in undeveloped property.

These findings are also consistent with the notion of a building cycle where property prices in a given area, in our case Tokyo, are highly correlated (Quigg, 1995). When it is profitable to exercise the option to develop one plot of land, it should be profitable on other property in the area as well, leading to a construction boom which we witnessed during the second half of the 1980s. The reverse occurs when it is not optimal to build resulting in a drastic decline in construction. The prediction is also supported by the fact that both the housing starts and real estate transactions hit its peak around 1986-88 and remained low throughout the period of 1991-93.

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Seller-Buyer	1986-88		1991-93	
Combination	Vacant	Developed	Vacant	Developed
Individual-Individual	14 (11.9%)	23 (14.3%)	93 (46.3%)	114 (41.6%)
Individual-Company	40 (33.9%)	30 (18.6%)	19 (9.5%)	18 (6.6%)
Company-Individual	12 (10.2%)	47 (29.2%)	39 (19.4%)	45 (16.4%)
Company-Company	20 (16.9%)	15 (9.3%)	7 (3.5%)	4 (1.5%)
Individual-Unknown	6 (5.1%)	15 (9.3%)	2 (1.0%)	11 (4.0%)
Unknown-Individual	0 (-)	2 (1.2%)	6 (3.0%)	12 (4.4%)
Company-Unknown	4 (3.4%)	0 (-)	1 (0.5%)	1 (0.4%)
Unknown-Company	3 (2.5%)	3 (1.9%)	0 (-)	0 (-)
Unknown-Unknown	19 (16.1%)	28 (17.4%)	34 (16.9%)	69 (25.2%)
Total	118 (100.0%)	161 (100.0%)	201 (100.0%)	274 (100.0%)

Table 1: Descriptive Statistics of Land Transaction Data. The ågures represent the number of transactions and corresponding properties belonging to each category of seller-buyer combination. The term \Company" includes real estate developers, brokers and other types of companies.

Number of Observations: 161
Adjusted R^2: 0.6154

Variable	Coeécient	t-statistic	Variable	Coeécient	t-statistic
$\tilde{a}_0$	7.7968	6.463	d_7	0.0651	0.33
$\ln q_1$	0.8233	9.12	d_8	0.2056	1.16
ln Age	-0.0834	5.39	d_9	0.0891	0.20
ln Dist	-0.2212	3.26	d_{10}	-0.0275	0.14
ln Road	0.2108	1.61	d_{14}	0.2508	1.93
$\ln y$	0.1943	1.09	d_{15}	0.0822	0.82
Q864	-0.2895	1.28	d_{16}	-0.0070	0.04
Q872	0.2636	2.68	d_{17}	-0.0401	0.22
Q873	0.4508	4.78	d_{18}	-0.0714	0.41
Q874	0.4643	3.85	d_{19}	0.2481	1.23
Q881	0.2347	1.51	d_{20}	0.6439	1.58
Q882	0.5718	3.09	d_{21}	-0.0789	0.39
d_1	0.0765	0.18	Z_1	-0.1396	0.87
d_2	-0.1085	0.46	Z_2	0.1208	0.55
d_3	0.2091	0.75	Z_3	0.2182	0.56
d_4	0.3159	2.34	Z_4	0.8888	1.39
d_5	0.2413	1.70	Z_5	0.0739	0.18
d_6	-0.2282	1.47			

Table 2: Hedonic Regression for 1986-88 Sample. For the ith property, d_1 Ä d_{21} : dummy variables for districts within Nerima-ward. Z_1 Ä Z_5 : zoning dummy variables for dai-ni-shu jukyo senyo chiiki, jukyo chiiki, kinrin shogyo chiiki, shogyo chiiki, and junkogyo chiiki respectively (please refer to footnote 12). Q is the quarterly dummy variable where the subscript denotes the year and quarter. q_1 is land area, Age is the building age in months, Dist is the distance to the nearest train station, Road is the width of the road in front of the lot, y denotes youseki-ritsu which is the ratio of the total area of the building to the area of the lot.

Number of Observations: 274
Adjusted R^2: 0.7920

Variable	Coeécient	t-statistic	Variable	Coeécient	t-statistic
$\tilde{a}_0$	8.8963	6.463	d_8	0.2359	2.51
ln q_1	0.8001	9.12	d_9	0.1807	1.69
ln Age	-0.0747	5.39	d_{10}	-0.0208	0.23
ln Dist	-0.1279	3.26	d_{11}	-0.0244	0.35
ln Road	0.1854	1.61	d_{12}	0.0248	0.58
ln y	0.3174	1.09	d_{13}	0.0588	0.54
Q914	-0.1039	1.28	d_{14}	0.1398	1.60
Q922	-0.0347	2.68	d_{15}	0.1150	1.03
Q923	-0.0489	4.78	d_{16}	-0.1163	0.71
Q924	-0.0684	3.85	d_{17}	0.0423	0.33
Q931	-0.0822	1.51	d_{18}	0.2783	1.26
Q932	-0.1397	3.09	d_{19}	-0.1381	1.13
d_1	0.1039	0.18	d_{20}	-0.0418	0.55
d_2	0.0316	0.46	d_{21}	-0.1120	1.59
d_3	0.2104	0.75	d_{22}	0.1418	1.08
d_4	0.0087	2.34	Z_1	0.0377	0.50
d_5	0.0603	1.70	Z_2	0.0899	0.81
d_6	-0.1356	1.47	Z_3	0.3363	2.38
d_7	0.0168	0.17	Z_4	-0.0812	0.50
			Z_5	-0.1030	0.89

Table 3: Hedonic Regression for 1991-93 Sample. For the ith property, d_1 Ä d_{22} : dummy variables for districts within Nerima-ward. Z_1 Ä Z_5 : zoning dummy variables for dai-ni-shu jukyo senyo chiiki, jukyo chiiki, kinrin shogyo chiiki, shogyo chiiki, and junkogyo chiiki, respectively (please refer to footnote 12). Q is the quarterly dummy variable where the subscript denotes the year and quarter. q_1 is land area, Age is the building age in months, Dist is the distance to the nearest train station, Road is the width of the road in front of the lot, y denotes youseki-ritsu which is the ratio of the total area of the building to the area of the lot.

	1986-88	1991-93	Diãerence
Option Premium	18.0458	18.5242	
	(12.2099)	(15.3236)	
Implied Volatility	36.5681	18.3835	**
	(16.156)	(14.8459)	
Number of observations	118	201	

Table 4: Option Premium and Implied Volatility. Option premium and implied volatility are in percent. The option premium is option value minus intrinsic value divided by the option value. Standard deviation in parenthesis. The diãerence in mean tests are t-statistics (null is that the mean values are the same). The signs (**) and (*) denote signiåcance for a two-tail test at the 1% and 5% level respectively.

		86-88			91-93	
Coeã.	I	Dif	I + Dif	I	Dif	I + Dif
ã$_0$	45279**	84076**	35580**	22849**	53046**	582.98
	(4.28)	(11.6)	(3.56)	(4.31)	(19.9)	(0.15)
ã$_1$	0.5725**		0.4720**	0.7962**		0.8400**
	(5.47)		(7.00)	(2.51)		(2.88)
ã$_2$		1.0704	0.7664*		1.3010**	1.3732**
		(0.38)	(1.40)		(2.23)	(4.04)
F-test			41.95**			215.56**
Adj. R^2	0.3162	0.2250	0.4218	0.3263	0.3231	0.6853

Table 5: Regression on Vacant Land Price on Intrinsic Value and Option Premium. t-statistic is in parenthesis. The t-statistics are for the null of ã$_0$ = 0, ã$_1$ = 1, and ã$_2$ = 1. F-test is for the null ã$_1$ = ã$_2$ = 1. The marks (**) and (*) denote signiåcance at the 1% and 5% signiåcance level.

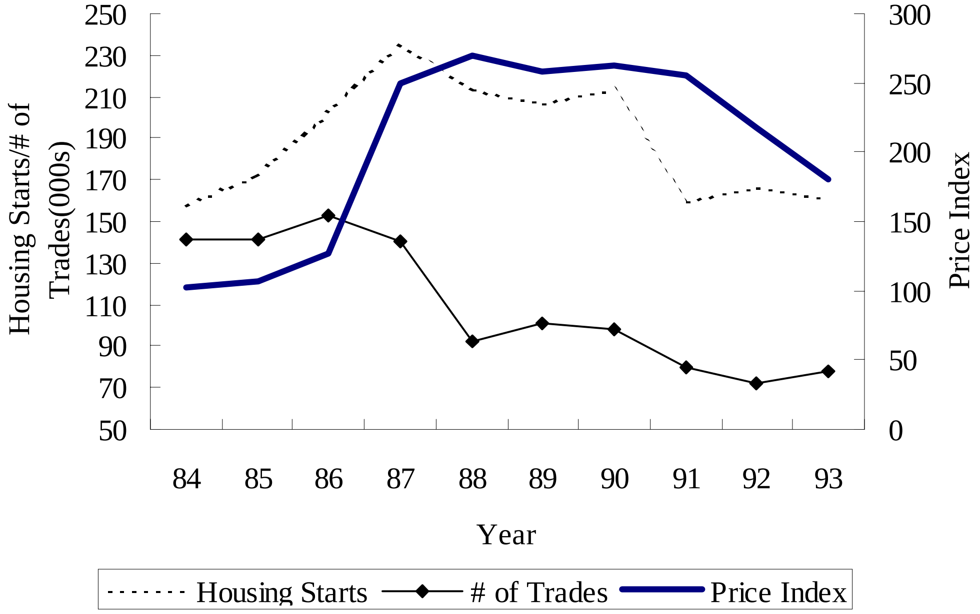

Figure 1: *Tokyo Real Estate Market: 1984-93*. The Land Price Index for Tokyo residential land prices (thick straight line) is provided by the National Land Agency. The housing starts statistics (dotted line, in thousands) is provided by the Ministry of Construction. The number of real estate transaction statistics (straight line with square markers, in thousands) is provided by the Ministry of Justice.

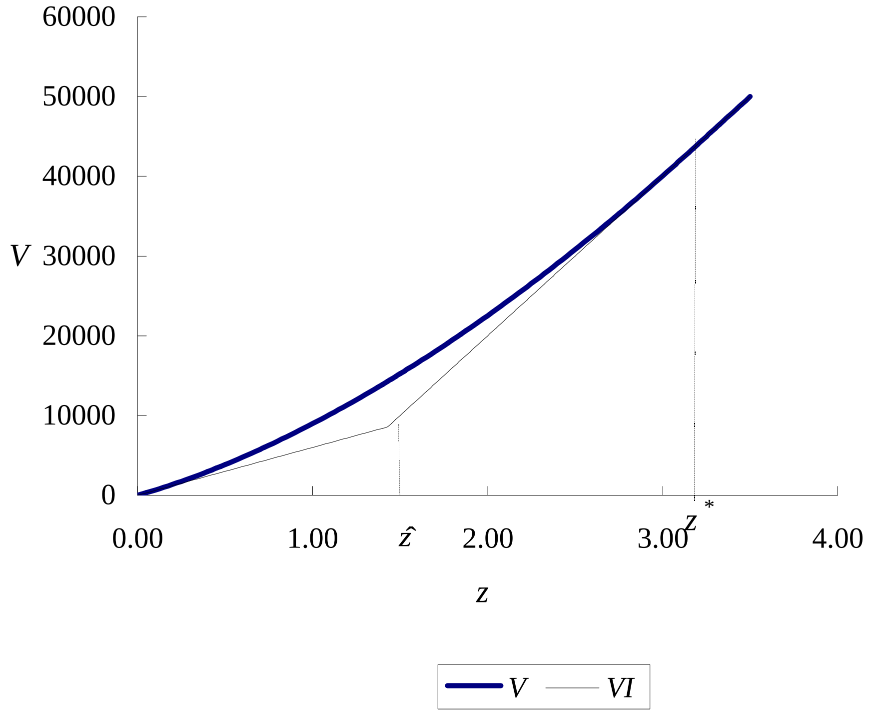

Figure 2: *Payoff Diagram of the Real Option to Develop Vacant Land*. Payoff diagram of the real option to develop with respect to $z \equiv P / X$. Parameter values are: X = 20,000, $w = 0.2$, $u_X = u_P = 0.02$, $i = 0.05$, b = 0.009, and s_X = 0.05.

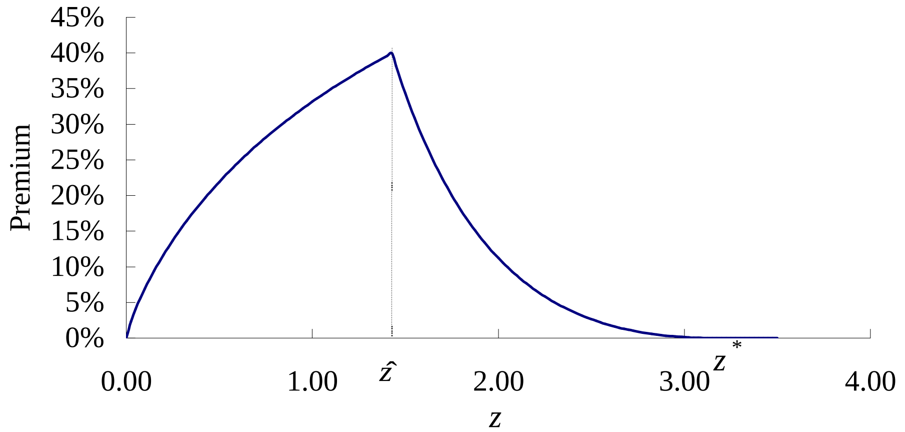

Figure 3: *Option Premium*. Option premium defined as $\left(V - V^I\right)/V$, with respect to $z \equiv P / X$. Parameter values are: X = 20,000, $w = 0.2$, $u_X = u_P = 0.02$, $i = 0.05$, b = 0.009, and s_X = 0.05.