Which "Greenness" is Valued? Evidence from Green Condominiums in Tokyo

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Which "Greenness" is Valued? Evidence from Green Condominiums in Tokyo*

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Abstract

This is one of the first researches on price differentials of green buildings in Asia. Using a rich set of data on condominium transactions and mandatory evaluation of environmental performance in Tokyo, we estimate the effects of itemized green scores on transaction prices. Although green condominiums are on average traded at a premium, the premium is mainly attributed to the building age and quality. After controlling for relevant attributes, we find significant price discounts for newly constructed green condominiums. However, green condominiums experience little depreciation at least during the initial years. Using itemized scores, we find that the long-life design mitigates price discounts, but other factors such as the use of eco-friendly materials, renewable energy, water reuse, and greening exacerbate discounts. Several possibilities are discussed including high future maintenance costs of green condominiums. (JEL: Q51, R31)

Key words: sustainability, green building, hedonic pricing, transaction price, residential real estate, Japan

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I. Introduction

The green building is a concept for buildings with better environmental performance. Green buildings typically emit less carbon dioxide (CO2). They have been drawing more attention in recent years because construction and operation of real estate account for a large share of total CO2. In Japan, about 40% of total CO2 emission is generated by the whole life cycle of real estate. (Architectural Institute of Japan, 2000)

The definition of green buildings varies by the evaluation system. In some systems it is defined merely by energy efficiency, but in others it is defined by a combination of various sustainability factors. For example, many green labeling systems such as LEED in the United States, CASBEE in Japan, and Tokyo Green Building Program used in the present research, construct comprehensive measures of environmental quality of real estate. Some of green factors are not directly linked to CO2 emission.

An important question about green buildings is whether and how their "greenness" is priced in the market. If green buildings are traded at sufficiently high prices, developers would build such buildings for profit. Then the transform of existing stock of real estate into green stock will be made smoothly by the market mechanism under the current institutional setting. If not, much stronger policy measures or further changes in consumers' consciousness are called for.

There are several potential sources of value premium for green buildings. The first is cost savings from purely technological reasons. If better heat insulator and more energy-efficient equipments are used in a building, they reduce operating expenses of the building. The reduced costs will be shared by the buyer and the seller with a certain ratio. The seller gets her share from a higher price, which compensates for increased costs of the green development. The second source is cost savings from public policy programs. The price can reflect not only current programs but also future ones. The third source is increased revenue for commercial buildings or owner's greater utility for residential buildings. Tenants of commercial buildings may be willing to pay higher rents if the use of green buildings is an important component of their corporate social responsibility. Home buyers may also be willing to pay higher prices if they are more satisfied by residing in green residential units.

However, the flip side is that there may be price discounts if these sources are negatively combined; prices will be lower if green features increase costs without much savings, public programs are not effective enough, and consumers of building services are not willing to pay enough.

In this research we study what kind of "greenness" is valued in real estate markets by using condominium data in Tokyo Metropolitan Area in Japan. We combine a rich set of data on condominium transactions with detailed evaluation of environmental performance that is mandated by Tokyo Metropolitan government. This is one of the first academic researches on price differentials of green buildings in Asia. In particular, this is the first in the world to estimate effects of green labeling by different factor of environmental scores.

More specifically, we first examine whether environmental evaluation under Tokyo Green Building Program generates any price differentials. In estimating the effect of green condominium indicator, we explore different controls for building characteristics and different specifications. Furthermore, we construct itemized relative scores in eight fields of environmental evaluation to estimate effects of environmental friendliness by field.

We find that green condominiums are on average traded at a premium if building characteristics are not controlled for, but the premium is mainly attributed to the building age and quality. After controlling for relevant attributes, we find significant price discounts for newly constructed greenlabeled condominiums. The negative effects range from 6% to 11%. However, green condominiums experience little depreciation at least during the initial years.

Regarding estimates for itemized scores in green evaluation, we find that the long-life design and mitigation of the heat-island phenomenon reduce price discounts. However, other items such as the use of eco-friendly materials, renewable energy, water reuse, and greening exacerbate price discounts. We estimate that a newly constructed green condominium with median green scores is traded roughly at 11% discount.

An explanation is based on user costs including those for maintenance and replacement of equipments. The long life design lowers user costs for the owner. The benefit can be significant in Japan where the average life of buildings is short. In contrast, greening, the use of eco-friendly materials, and water reuse may significantly increase future operating expenses and capital expenditures. Such benefits and costs in the future would be capitalized into the initial price of a condominium.

The price discount indicates that homeowners are not yet willing to pay significantly higher prices for living in green condominiums. It also shows that the current and expected future policy measures do not create a significant benefit for green condominiums at this moment. Much stronger policy measures are called for in order to overcome price discounts and even generate price premia for autonomous diffusion of green buildings.

The paper is organized as follows. Section II is the review of related literature. In Section III, we summarize data for transaction prices and green building evaluation used in the study. Section IV presents the empirical analysis and discussion of the results. Section V concludes.

II. Literature

More cases studies and research reports on green buildings are published as concerns on global warming increase. However, the majority of previous researches is non-academic ones from engineering perspectives, and focuses more on cost issues than on values.

For example, California's sustainable building task force (2003) conducts case studies of 33 buildings on technical aspects of green buildings. Urban Land Institute publishes a number of books on green buildings on costs of construction and operation.

Some industry researches deal with values of and returns to green buildings. (Pramerica Real Estate Investors, 2007; RREEF, 2007, 2008, 2009; USGBC, 2008) Although some positive results on green building investments are presented, the research methodologies are not necessarily satisfactory.

Our research is one of two first researches on a comprehensive measure of green buildings, which is not restricted to energy efficiency. The other research is done by Yoshida, Quigley, and Shimizu (2010) who use a different set of data and analyze how itemized scores in Tokyo Green Labeling System for Condominiums and CASBEE are associated with differentials in asking price of new condominiums. They find that developers add a 4.7% premium on asking prices of newly constructed green condominiums. The asking price is discounted by about 5% when condominiums are actually sold for both green and non-green ones. They do not find that the premium completely disappears after sale negotiations; i.e., a part of the premium remains in transaction prices. The different result may be arising due to the limited number of transaction sample in their study.

Closely related researches are the following. By using an energy efficiency measure, Dian and Miranowski (1989) reports that energy efficiency leads to a higher residential price. More recently, Brounen and Kok (2009) analyze the effect of an energy-saving label in the Netherlands on transaction prices of housing. They find about 3% premium in prices after controlling for location and building quality.

On office buildings, Eichholtz et al. (2010) study US office markets by using data from Energy-Star and LEED. They find about 3% rent premium for 694 green office buildings after controlling for differences in quality and location. Fuerst and Patrick (2008) and Miller et al. (2008) also use Energy-Star and LEED data to find premia in rents or prices. Miller et al. (2008) find no rent premium but 6% to 10% premium on transaction prices. Fuerst and Patrick (2008) report about 5% premium in rents and 30% premium in transaction prices. Although LEED is a comprehensive evaluation system for green buildings, they do not provide analysis of itemized effects.

III. Data

A. Tokyo Building Environmental Plan

The Tokyo Metropolitan Government launched its Basic Plan for Environmental Protection in 1997, and enacted the Tokyo Metropolitan Environmental Security Ordinance in 2000.[1] Based on the ordinance, the government launched Tokyo Green Building Program in 2002, which was reinforced in 2005, 2007, and 2009.[2] The amendment in 2005 includes the creation of Tokyo Green Labeling System for Condominiums, by which the developer of a large-scale condominium project is required to announce its itemized green scores to potential buyers.

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[1] The ordinance No. 215, whose formal name is, "Tomin no Kenko to Anzen wo Kakuho Suru Kankyo ni Kansuru Jourei."

[2] Tokyo Green Building Guidelines are published in Tokyo Metropolitan Notification No. 384 on March 28, 2002. See http://www2.kankyo.metro.tokyo.jp/sgw/English/Tokyo%20Green%20BUilding%20Program.pdf for more information.

The purpose of the program is to require large building owners to submit Tokyo Green Building Plan and announce the submitted plan and related materials on Tokyo Metropolitan Government's website and thereby to encourage building owners to carry out voluntary environment-conscious efforts and create a market that would highly rate environmentally sound and high-quality buildings and structures.

A building owner is subject to the ordinance if the owner intends to newly construct or expand a building whose total floor space exceeds 10,000 m2. Regardless of whether the building owner is in the private sector or in the public sector, the ordinance applies to all categories of buildings including residential buildings and office buildings. The total floor space is calculated for each building, and the building owner does not have to add up the floor spaces of all buildings in the same promises. As of January 28, 2010, 1,154 buildings are evaluated under the program.

A big advantage of Tokyo Green Building Program for this research is that the program is mandatory to new construction or renovation exceeding 10,000 m2 in floor area. Therefore, unlike other green labeling systems on voluntary basis, Tokyo's program is in principle free from the sample selection problem. Another advantage is that the Tokyo government publishes itemized scores in eight fields: 1) reduction of thermal loads, 2) use of renewable energy, 3) energy-saving, 4) use of eco-friendly materials, 5) longer life of the building, 6) water circulation, 7) greening, and 8) mitigation of the heat island phenomenon. A building is given one points to four points in each field. The maximum points are different in each field and can be changed at each amendment.

In our analysis, we first construct an indicator variable that identifies whether a building is evaluated under Tokyo Green Building Program or not:

$$I_{g,i} = \begin{cases} 1 & \text{if Building i is evaluated,} \\ 0 & \text{otherwise.} \end{cases}$$

Next we construct a measure of relative scores for evaluated buildings in each of the eight fields described above. The maximum possible points are different by field. In some fields score is either 1 or 2, but in other fields score can be 1, 2, 3, or 4. As a result, 1 point in a field can be different from 1 point in other fields. Therefore, we construct the relative score by dividing raw score by the maximum possible score in each field. If Building i gets a raw score of $S_{m,i}$ in Field m, in which the maximum possible score is $\bar{S}_m$, the relative score, $L_{m,i}$, is defined as $L_{m,i} = S_{m,i}/\bar{S}_m$.

In addition to the relative score, we construct indicator variables for each relative score. It is because the scores in the program are not cardinal. The relative scores should be interpreted as categorical variables. If there are N_m distinct values of relative scores in Field m, and if $L_{m,i}$ for Building i is the n-th lowest value in the field, the indicator variable, $I_{mn,i}$, equals to unity. That is,

$$I_{mn,i} = \begin{cases} 1 & \text{if } L_{m,i} \text{ is the n-th lowest value in Field m,} \\ 0 & \text{otherwise,} \end{cases}$$

$$\text{for } m = 1, \dots, 8; n = 1, \dots, N_m$$

B. Transaction Price Data

The transaction price data of condominium units in Tokyo are obtained from the Transaction Price Information Service (TPIS) that is jointly managed by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) and Tokyo Association of Real Estate Appraisers (TAREA). The TPIS provides transaction price information and associated attributes such as location, size, zoning and property use. The MLIT produces the information by combining three data sources: 1) the registry data obtained from the Ministry of Justice (MOJ) on transactions of raw land, built property, and condominiums, 2) survey results answered by property buyers, and 3) field survey conducted by real estate appraisers.

A unique advantage of the TPIS data is their quality. The data set contains extremely rich set of property attributes. The data set is a combination of three distinct data sources, which allows us to check the consistency and accuracy of the data.

The data collection scheme is the following. The MOJ, which administers the national real estate registration system, provides MLIT the updated information on ownership transfers.[3] The MOJ's registry information includes location, plot number, type of land use, area, dates of receipt and contract, and name and address of the new owner. However, the registry does not record transaction prices. For each record on the registry, the MLIT sends questionnaires to each of the new owners and collects information on the transaction price, property size, and reason of the transaction. Based on the collected data, real estate appraisers conduct field survey on each property to record necessary information for appraisal such as building height, frontal road, distance from the nearest station, site shape, and land use. The information is finally compiled by MLIT.

The process typically takes three months. For example, registry data of April 2008 are obtained from the Ministry of Justice at the end of May 2008, and questionnaires are posted to buyers at the beginning of June 2008, which are to be collected by the end of the same month. A small portion of the cases

[3] There are ten different kinds of real property rights to be registered: exclusive and absolute right to real property, right to superficies, easement right, permanent tenancy right, preferential right, pledge right, mortgage right, leasehold right, stone-quarrying right, and redemption right.

(about 3% of the total) are omitted after the merged data are checked. Cases are omitted if field survey results are obviously different from questionnaire results or if the property size is below 10 m^2.

For example, between July 2005 and December 2007, 6.3 million transfers of ownership are registered for land, built property, and condominium ownership, of which 1.34 million transfers are subject to the MLIT survey. Eventually, 334 thousand replies are collected (29.2 % collection rate), and 220 thousand records are published after excluding errors.

In the original sample of condominiums in Tokyo, 41,560 transactions are included between 2002 and 2009. However, in a part of the sample, some necessary information is missing. After removing incomplete observations, we maintain 34,862 observations.

The data set includes very rich information on the attributes of condominium units and buildings. After dropping the variables that contain significant number of missing values, we use the variables that are listed in Table 1. The dependent variable is logarithm of price per square meter. The explanatory variables are classified into five categories: 1) room attributes, 2) transaction characteristics, 3) location, 4) building size, and 5) building quality.

It is noteworthy that we include indicator variables for jurisdictions and railway lines as location variables in order to control for unobserved heterogeneity in location. The jurisdiction is as important in Tokyo as anywhere else because of local public services, amenities, and local taxes. But the railway line is also important in Tokyo because frequent use of railway system creates railway-based communities and railway-based residential sorting. Transaction timing is also controlled for by indicator variables for quarter-year of transaction.

Table 1: List of explanatory variables

Variable	Unit/Category
1) Room attributes	
Log floor area	ln (m2)
Floor number	
Floor plan	Indicators for 1K, 1DK, 2DK, 1LDK, 2LDK, 3LDK, & 4-LDK
2) Transaction	
Transaction quarter	Indicators for quarter-year of transaction
Buyer type	Indicators for individual, company, real estate firm, and public entity
Seller type	Same as above
3) Location	
Jurisdiction	Indicators for 23 wards and cities
Station Size	Number of railway lines coming to the nearest station
Railway Line	Indicators for railway lines
Distance to Station	Road distance in kilometers
Zoning	Indicators for neighborhood commercial, commercial, exclusive industrial, industrial, quasi industrial, low-rise residential 1, low-rise residential 2, medium-to-high-rise residential 1, medium-to-high-rise residential 2, residential 1, residential 2, and quasi residential.
Maximum Building Coverage Ratio	%, as defined by zoning regulation
Maximum Floor-to-Area Ratio	%, as defined by zoning regulation
4) Building Size	
Lot area	Square meters
Number of units	Number of units in the building
Stories above ground	Number of stories above ground
Stories below ground	Number of stories below ground
5) Building Quality	
Building structure	Indicators for steel-reinforced concrete, reinforced concrete, steel, wooden, and blocks
Building age	Years after completion of the building
Superintendent	Indicator for having superintendents

Table 2 summarizes the descriptive statistics for samples with and without the green evaluation. The left column is for non-green condominiums and the right column is for green condominiums. It is clear that green condominiums are traded at significantly higher prices. The mean transaction price of green condominiums is 56 million yen, which is more than the double of 27 million yen for non-green condominiums. However, green condominium units also have larger floor area. After computing unit prices per square meter of floor area, the price differential shrinks but still remains.

Green condominiums are also taller (Stories above ground), have larger lot (Lot area), have more units (Number of units), and younger (Building age). These differences in size and quality must be responsible for the price differential. It is important to control for quality differences carefully in order to isolate price differentials of green buildings.

Table 2: Descriptive Statistics

	Non-Green Condominiums			Green Condominiums		
	Number of observations: 33,390			Number of observations: 1,472		
Variables	mean	standard deviation	median	mean	standard deviation	median
Transaction Price (yen)	2.72E+07	3.03E+07	2.27E+07	5.58E+07	5.52E+07	4.50E+07
Price (yen) per sq. m.	645500.0	482025.2	559451.5	772572.5	551089.2	711700.2
ln (Price per sq. m.)	13.2207	0.5772	13.2347	13.4681	0.3846	13.4754
Floor area (sq. m.)	0.4620	0.3086	0.4760	0.7255	0.4081	0.7201
ln (Floor area)	-0.9393	0.5956	-0.7423	-0.3683	0.2917	-0.3284
Floor number	5.4662	4.6918	4	12.1841	10.0357	9
Station size (number of lines)	1.5302	1.1620	1	1.8132	1.3746	1
Distance to station (100m)	0.6173	0.4764	0.5200	0.6913	0.4736	0.6300
Max. building coverage ratio	0.6959	0.2165	0.6	0.6493	0.0956	0.6
Max. floor to area ratio	3.5357	1.5707	3	3.4056	1.4342	3
Lot area	0.3181	0.8961	0.0836	1.2491	1.1884	0.8499
Number of units	0.0995	0.1881	0.0530	0.4220	0.3227	0.3380
Stories above ground	9.7571	6.3896	9	23.7208	12.5745	20
Stories below ground	0.2491	0.5545	0	0.9524	0.9625	1
Building age	12.8447	11.0860	10	1.8116	2.1724	1
Superintendent	0.8921	0.3102	1	0.9959	0.0637	1

IV. Empirical Analysis by Hedonic Approach

A. Hedonic Model

We adopt hedonic approach to the estimation of the green effect on transaction prices. The hedonic approach is theoretically formalized by Rosen (1974), and is widely used in the study of real estate valuation. The idea is to regard housing as a bundle of characteristics such as lot size, building size, and location. Then under some conditions, it is shown that housing prices in spatial equilibrium implicitly reveal a real-valued pricing function $p(\mathbf{z}) = p(z_1, \ldots, z_n)$ relating prices and the n-vector of characteristics, $\mathbf{z}$. Then, the market price associated with characteristic, z_i, holding all else constant, is given by $\partial p/\partial z_i$, assuming continuity of z_i and differentiability of p.

We investigate how green buildings are evaluated in the market in two ways. First, we estimate the effect of being evaluated in Tokyo Green Building Program on transaction prices. The indicator variable, $I_{g,i}$, defined in Section III is used as the indicator for the green building. Second, we estimate effects of itemized scores in the program by using indicator variables, $I_{mn,i}$, that are also defined in Section III.

B. Analysis by Green Building Indicator

In our first analysis using the green indicator, we estimate six variations of the following model by with different control variables. The logarithm of transaction price of Room j in Building i at Time t ($\ln P_{ijt}$) is regressed on a constant, the indicator variable, $I_{g,i}$, and various hedonic characteristics, $X_{kf,ijt}$. Category k, $k = 1, \ldots, 5$, contains F_k variables indexed by f. The hedonic characteristics variables X include indicator variables for jurisdiction and railway to control for unobserved heterogeneity in location.

$$\ln P_{ijt} = b_0 + b_g I_{g,i} + \sum_{k=1}^{5} \sum_{f}^{F_k} b_{kf} X_{kf,ijt} + \varepsilon_{jt} \qquad (1)$$

The first variation does not include any attribute in order to measure mean difference between green buildings and non-green buildings. We add one category of attributes at a time; only room characteristics are included in the second variation, room and transaction characteristics are included in the third variation, and so on. The sixth version is the full model under this specification.

Table 3 presents the OLS regression results for the green building indicator. Column (1) reports the results for the first variation, in which no hedonic characteristics are included. The estimated green coefficient, $\widehat{b_g}$, represents the mean difference between the green condominiums and the non-green ones when differences in hedonic characteristics are ignored. The green condominiums are on average traded for about 26% higher prices. As more hedonic characteristics are added in Column (2) through Column (5), the adjusted R-squared increases while the green coefficient gradually decreases. In Column (5), the green coefficient is reduced to 0.1984, but remains significantly positive, when 166 explanatory variables are used including indicators for jurisdictions and railways.

When the variables for building quality are included, the result fundamentally changes even though only one numeric variable and four indicator variables are added. In Column (6), the green coefficient turns to negative (-0.0563), which is statistically significant at 1% level, and the adjusted R squared jumps up to 0.637. This result suggests that the estimated green coefficient is significantly affected by correlations between the building quality variables and the green building indicator. Without controlling for building quality, the estimated coefficient for the green indicator is subject to the omitted variables bias. After controlling for building quality, green condominiums are found to be traded for about 5.6% lower prices. We will discuss this negative effect after presenting the results of robustness checks and the estimation results of itemized effects.

Table 3: Regression Results on the Green Building Indicator
(dependent variable: logarithm of price per square meter)

	(1)	(2)	(3)	(4)	(5)	(6)
$\widehat{b_g}$ (Green Building)	0.2626*** (0.0104)	0.2590*** (0.0096)	0.2384*** (0.0102)	0.2176*** (0.0089)	0.1984*** (0.0099)	-0.0563*** (0.0084)
Controls						
Room	-	Yes	Yes	Yes	Yes	Yes
Transaction	-	-	Yes	Yes	Yes	Yes
Location	-	-	-	Yes	Yes	Yes
Bldg. size	-	-	-	-	Yes	Yes
Bldg. quality	-	-	-	-	-	Yes
Constant	13.2107*** (0.0030)	13.2977*** (0.0531)	13.1645*** (0.0540)	13.3578*** (0.0611)	13.3870*** (0.0593)	14.0386*** (0.0513)
Adjusted R^2	0.00788	0.186	0.242	0.445	0.455	0.637
Number of explanatory variables	1	11	36	162	166	171
N	38680	37917	37914	37906	35927	34862

The table summarizes the estimation results of six variations of Equation (1) for different control variables. The White heteroscedasticity-consistent standard errors are in parentheses. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively. Location controls include indicator variables for jurisdictions and railway lines. The timing of transaction is controlled by quarter-year dummies in transaction controls.

The signs of estimated coefficients for other control variables, which are provided on the author's website, are generally as expected.[4] For the full model shown in Column (6), the transaction price per square meter is higher if the unit is on a higher floor (0.0068 per floor), the unit is smaller (0.0752 per log floor area), the unit is a one-room type, the condominium is closer to a railway station (0.1316 per kilometer), the nearest station has more railway lines (0.0183 per line), zoning is residential, there are superintendents (0.0413), the seller is a real estate firm or a company, and the buyer is an individual.

C. Robustness Checks and Additional Findings

Now we conduct additional investigations and robustness checks of the previous result that green buildings negatively affect transaction prices. First, we separate each variable for building quality to see which quality variable affects the green coefficient most. The building quality variables are building age, building structure, and superintendent.

Second, we estimate the full model with all the attributes by Least Absolute Deviation (LAD) method in order to reduce the influence of outliers on the estimation.[5] The LAD estimator is a median estimator and is less affected by the skewness or fat tails of the disturbance distribution. Third, we estimate the full model in the sub-sample in which one-room units are excluded. One-room units are often built and sold for rental purposes, and those units could be traded for quite different motivations. We are concerned about the possibility that such non-standard units are driving the result.

Given the result from the first robustness check that the building age is a critical attribute in estimation, we include, as the fourth variation, quadratic

[4] Please see www.personal.psu.edu/juy18.

[5] The LAD estimator in our application is the solution to the problem,

$$\min_{b_0,b_g,b_{kf}} \sum_j \sum_t \left| \ln P_{jt} - b_0 - b_g I_{g,i} - \sum_{k=1}^{5} \sum_{f=1}^{F_k} b_{kf} X_{kf,ijt} \right|$$

terms of building age and building size. This specification allows for non-linear relations between these variables and the log transaction price. Fifth, we include an interaction term of the green building indicator and building age to see if green buildings depreciate in a different manner. A different rate of depreciation may well arise because a longer life of a building is evaluated in Tokyo Green Building Program. Finally, we estimate the version with the interaction term in a subsample in which projects completed before 2003 are excluded. We limit the sample in order to focus on depreciation rates during early years and to better match the sample of green buildings with that of other buildings. Green condominiums are generally younger than seven years old since Tokyo Green Building Program has only eight years of history.

Table 4 presents the results of robustness checks. A clear conclusion is that the estimated coefficient for the green building indicator is negative after building age is taken into account. We obtain even larger effects of green buildings on transaction prices when the model specification is more flexible in building age.

Column (1), (2), and (3) compare which variable for building quality affects the estimated green coefficient most. We find that the building age is the key variable to be controlled for in estimating the green coefficient correctly. Without any variable for building quality, the estimate of the green coefficient is 0.1984 (Column (5) in Table 3.) The inclusion of building age changes the sign of the estimate to -0.570, which is close to the one in the full model. (Columin (1)) The inclusion of building structure variables also affects the estimate, but to a lesser extent. (Column (2)) The inclusion of superintendent indicator does not alter the estimate. (Column (3))

In column (4), we present the result estimated by LAD. Compared to the OLS estimate of -0.0563, the LAD estimate exhibits a larger effect of -0.0803.

Table 4: Robustness Checks of the Green Building Effect
(dependent variable: logarithm of price per square meter)

	(1) Age only	(2) Structure only	(3) Super-intendent	(4) LAD
$\widehat{b_g}$ (Green Building)	-0.0570*** (0.0084)	0.1326*** (0.0103)	0.1996*** (0.0100)	-0.0803*** (0.0074)
Controls				
Green building x building age	-	-	-	-
Bldg. age	-0.0261*** (0.0002)	-	-	-0.0255*** (0.0001)
$[\text{Bldg. age}]^2$	-	-	-	-
Bldg. structure	-	Yes	-	Yes
Superintendent	-	-	0.0206** (0.0089)	0.0256*** (0.0043)
Room	Yes	Yes	Yes	Yes
Transaction	Yes	Yes	Yes	Yes
Location	Yes	Yes	Yes	Yes
Bldg. size	Yes	Yes	Yes	Yes
$[\text{Bldg. size}]^2$	-	-	-	-
Constant	13.7283*** (0.3495)	13.5718*** (0.0400)	13.5145*** (0.0440)	13.7762*** (0.0199)
Adjusted R^2	0.6363	0.4834	0.4573	0.445
Number of explanatory variables	167	169	167	176
N	34862	34862	34862	34862

Table 4 (Continued): Robustness Checks of the Green Building Effect
(dependent variable: logarithm of price per square meter)

	(5) Studios excluded	(6) Quadratic size & age	(7) Green x age	(8) Since 2003
$\widehat{b_g}$ (Green Building)	-0.0757*** (0.0089)	- 0.1206*** (0.0088)	-0.1083*** (0.0100)	-0.0604*** (0.0145)
Controls				
Green bldg. x Bldg. age	-	-	0.0279*** (0.0023)	0.0392*** (0.0050)
Bldg. age	-0.0227*** (0.0002)	-0.0456*** (0.0007)	-0.0261*** (0.0002)	-0.0513*** (0.0028)
[Bldg. age]^2	-	0.0006*** (0.0000)	-	-
Bldg. structure	Yes	Yes	Yes	Yes
Superintendent	Yes	Yes	Yes	Yes
Room	Yes	Yes	Yes	Yes
Transaction	Yes	Yes	Yes	Yes
Location	Yes	Yes	Yes	Yes
Bldg. size	Yes	Yes	Yes	Yes
[Bldg. size]^2	-	Yes	-	-
Constant	13.6603*** (0.0349)	13.1473*** (0.0586)	13.6920*** (0.0364)	13.1537*** (0.0798)
Adjusted R^2	0.640	0.653	0.637	0.604
Number of explanatory variables	171	175	172	172
N	24909	34862	34862	11703

The table summarizes the estimation results of alternative specifications and robustness checks. The White heteroscedasticity-consistent standard errors are in parentheses. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively. Location controls include indicator variables for jurisdictions and railway lines. The timing of transaction is controlled by quarter-year dummies in transaction controls. Pseudo-R^2 reported for LAD regression.

Therefore, the outliers and distributional irregularity are not producing the negative effect. Rather, such irregularity attenuates the estimate.

In column (5), when we exclude one-room units from the sample, the estimate again exhibits a larger effect of -0.0757 than -0.0563 in the full sample. For standard-sized units of condominium, greenness is associated with a greater negative effect on price than for smaller one-room units. One-room units are in fact found to be different from other standard-sized units, but those units attenuate the negative effect. It may be the case that the green design does not create a big difference for smaller one-room units.

In Columns (6), (7), and (8), the building age is treated with a greater care, given its importance in estimating the green coefficient. When we include quadratic terms of age and size variables in Column (6), the estimated green coefficient doubles to -0.1206. The quadratic term of building age is significant at 1% level and enters positively. The negative coefficient on age roughly doubles to -0.0456. This shows that the depreciation rates are not constant over ages but much faster for younger buildings. The omission of this nonlinear effect of age creates a systematic pattern in the error term such that younger buildings tend to have positive errors. The green condominiums, which are generally younger, are associated with the positive errors. Therefore, the estimated green coefficient is biased upward when nonlinearity of depreciation rates are omitted. We confirm this by doubling green coefficient.

Column (7) shows the result when we include an interaction term of building age and the green indicator. Again we obtain a stronger effect of the green indicator, -0.1083. This value is the estimated green discount for new buildings when age equals to zero.

An additional important finding is that depreciation rates are different for green condominiums. Non-green condominiums depreciate on average at about 2.6% per year. In contrast, the depreciation rate of green condominiums is about zero. The interaction term is positive 0.0279 and significant at 1%. The sum of the estimates for age and the interaction term becomes 0.0018, which cannot be distinguished from zero. Green condominiums are sold initially at 11% discount, but do not depreciate much. Roughly four years later, the value of green condominiums exceeds that of non-green ones.

Column (8) presents estimates of the differential depreciation rates in a restricted sample of being built after 2002. The result generally agrees to the previous one in Column (7). The depreciation rate for non-green condominiums becomes higher at about 5.1% per year during initial seven years. The estimate for the interaction term is again positive and significant at 1% level. The estimated depreciation rate for green condominiums is about 1.2%. The initial discount for green condominiums is reduced to about 6.0%. After five years from sale, the value of green condominiums exceeds that of non-green ones.

D. Analysis by Itemized Green Scores

In this section we present estimation results for itemized green scores. As summarized in Section III, there are eight fields of criteria in Tokyo Green Building Program. We estimate coefficients of indicator variables for relative scores in each of eight fields, in addition to the green indicator. Since the baseline effect of green condominiums is captured by the green indicator, coefficients for itemized scores capture deviations from the baseline effect. The estimation equation is,

$$\ln P_{ijt} = b_0 + b_g I_{g,i} + \sum_{m=1}^{8} \sum_{n=2}^{N_m} b_{mn} I_{mn,i} + \sum_{k=1}^{5} \sum_{f}^{F_k} b_{kf} X_{kf,ijt} + \varepsilon_{jt}, \qquad (2)$$

where $I_{g,i}$ is the green indicator, and $I_{mn,i}$ is the indicator variable that equals to unity if the relative score for Building i in Field m is the n-th lowest value for $n = 2, \ldots, N_m$. The lowest value is zero for each field.

Table 5 presents the estimation result. Estimated coefficients for itemized green scores are shown only if they are significant at 0.1 or lower. We estimate five variations of Equation (2). Columns (1) and (2) are results by OLS and LAD, respectively. Column (3) is the OLS result when quadratic terms of building age and building size variables are included. Column (4) is the OLS result when heterogeneous depreciation is allowed by including the interaction term between building age and the green indicator. Column (5) is the same as Column (4) except that the sample is limited to condominiums built since 2003.

Among eight fields of green investments, the longer life of building (i.e., m=5) exhibits very strong positive effects. In Column (1), estimated effects are about 0.134, 0.087, and 0.247 when relative scores are 0.33, 0.67, and 1, respectively. The positive effects are even larger in Column (3), (4), and (5) when the depreciation is better modeled. The median score in this field is 0.67, for which effects range from 0.087 to 0.347 depending on estimation.

Large positive effects are also found for the mitigation of heat-island phenomenon (i.e., m=8). For the relative score of 0.33, positive effects range from 0.151 in Column (5) to 0.262 in Column (4). However, there are only 102 condominium units getting positive scores in this field, of which78 units, or 5% of total green units, get 0.33 points. Therefore, such strong positive effects do not affect the majority of green condominiums.

Other fields are generally associated with negative effects, which augment the negative baseline effect. In particular, effects of the use of eco-friendly materials are important for the overall green effect because about a half of condominium units receive 0.5 points in this field. The units receiving

0.33 points are discounted by 0.050 to 0.098, and those receiving 0.5 points are discounted by 0.029 to 0.054 in addition to the baseline discount.

The water circulation is also associated with large negative effects. The estimated discounts range from 0.122 to 0.162 for those with full score, which account for 14% of green condominium units. The remaining 86% of green units receive either zero point or 0.5 point, in which case no additional discount is estimated.

The greening also tends to result in discounts. In Column (1), estimated effects range from -0.049 to -0.276. The estimated effects are stronger for the LAD estimation shown in Column (2) and for the model with quadratic terms shown in Column (3), but become insignificant in Columns (4) and (5).

The energy saving is also associated with large price discounts. Discounts range from -0.114 to -0.197 for 0.5 point, and from -0.108 to -0.124 for 1 point. The effects tend to be stronger when the age variable is better modeled. The reduction of thermal loads and renewable energy do not exhibit consistent results across different variations. In most specifications, these effects are insignificant.

The baseline effect of green condominiums (the first row) is negative for each specification. At first glance, the effect looks stronger than in Tables 3 and 4. However, the baseline effect cannot be directly compared with the green effect estimated without itemized scores. The baseline effect can be interpreted as price differential for a hypothetical green condominium that gets zero point in every field.

Table 5: Regression Results on Itemized Green Scores
(dependent variable: logarithm of price per square meter)

	Score	(1) OLS	(2) LAD	(3) Quadratic Size & Age	(4) Green x Age	
$\widehat{b_g}$ (Green Building)		-0.1125***	-0.0868	-0.1966***	-0.1888***	
1. Reduction of thermal loads	0.5	-	-	0.0457*	-	
	1	-	-	-	-	
2. Renewable energy	0.33	-	0.1481*	-	-	
	0.5	-0.0379*	-	-	-	
3. Energy saving	0.5	-0.1184*	-	-0.1143*	-0.1148*	
	1	-0.1082*	-	-0.1244**	-	
4. Eco-friendly materials	0.33	-0.0642***	-0.0775***	-0.0977***	-0.0503**	
	0.5	-0.0393**	-0.0287*	-0.0286*	-0.0319*	
5. Longer life of building	0.33	0.1340***	-	0.1671***	0.1542***	
	0.67	0.0869**	-	0.1005***	0.1099***	
	1	0.2468***	0.1814*	0.2704***	0.2830***	
6. Water circulation	1	-0.1618***	-0.1224***	-0.1362***	-0.1483***	
7. Greening	0.25	-0.2759***	-0.2953***	-0.3673***	-0.2273***	
	0.33	-	-0.0469***	-0.0296*	-	
	0.67	-	-	-	0.0777*	
	0.75	-0.1511**	-0.1692**	-0.2469***	-	
	1	-0.0488**	-0.0977***	-0.0438*	-	
8. Mitigation of heat island	0.33	0.2453***	0.1690***	0.2272***	0.2624***	
Contols						
Green bldg x Bldg. age		-	-	-	0.0266***	
Bldg. age		-0.0261***	-0.0255***	-0.0457***	-0.0261***	
[Bldg. age]^2		-	-	0.0006***	-	
Bldg. structure		Yes	Yes	Yes	Yes	
Superintendent		Yes	Yes	Yes	Yes	
Room, transaction, and location		Yes	Yes	Yes	Yes	
Bldg. size		Yes	Yes	Yes	Yes	
[Bldg. size]^2		-	-	Yes	-	
Constant		13.6901***	13.7713***	13.7499***	13.6897***	1
Adjusted R^2		0.638	0.5549	0.651	0.638	
Number of explanatory variables		194	199	198	195	
N		34859	34859	11700	34859	

The table summarizes the estimation results of Equation (2). Estimated coefficients for itemized scores are shown only if they are significant at 0.1 or lower. Significance at the 0.10, 0.05, and 0.01 levels are indicated by *, **, and ***, respectively. The White heteroscedasticity-consistent standard errors are used. Location controls include indicator variables for jurisdictions and railway lines. The timing of transaction is controlled by quarter-year dummies in transaction controls. Pseudo-R^2 reported for the LAD regression.

In Table 6, we compute the total green effect for a hypothetical condominium that gets median scores for all fields. Median scores for fields 1 through 8 are 0.5, 0, 0, 0.5, 0.67, 0.5, 0.33, and 0, respectively. Median scores are almost identical to modes. In general, a negative baseline effect tends to be partially offset by a positive effect of longer life, but enhanced by negative effects of eco-friendly materials and greening.

The total effect for the median condominium is -0.065 by OLS and -0.076 by LAD. (Columns (1) and (2)) When quadratic terms for building age and building size are included, the total effect is magnified to -0.109. (Column (3)) When the interaction term between building age and the green indicator is included, the total effect becomes -0.111, which does not change even if we limit the sample to condominiums built since 2003. The results are consistent to each other in Columns (3), (4), and (5) when the age-related depreciation is better modeled.

Finally, estimated results on depreciation are similar to those in Tables 3 and 4; green condominiums are less subject to depreciation. With a constant and homogeneous depreciation rate assumed in Columns (1) and (2), the annual depreciation rate is about 2.6%. When age-dependent but homogeneous depreciation rates are introduced by the quadratic term, the initial depreciation rate is about 4.6% but rates become lower with age. For a 10 year-old building, the depreciation rate becomes about 3.5%.[6] When heterogeneous depreciation rates are allowed in column (4), the average rate is about 2.6% for non-green condominiums, but about 0% for green ones. When the sample is limited to newer condominiums, the average depreciation rate becomes about 5% for non-green ones and 1.5% for green ones. (Column (5))

[6] Based on the estimates in Column (3), the marginal depreciation rate for X year-old building is -0.0457 + 0.0006X.

Table 6: Effects for a Condominium with Median Scores

	Median Score	(1) OLS	(2) LAD	(3) Quadratic Size & Age	(4) Green x Age
1. Reduction of thermal loads	0.5			0.0457	
2. Renewable energy	0				
3. Energy saving	0				
4. Eco-friendly materials	0.5	-0.0393	-0.0287	-0.0286	-0.0319
5. Longer life of building	0.67	0.0869		0.1005	0.1099
6. Water circulation	0.5				
7. Greening	0.33		-0.0469	-0.0296	
8. Mitigation of heat island	0				
(A) Sum of itemized scores		0.0476	-0.0756	0.088	0.078
(B) Baseline effect		-0.1125		-0.1966	-0.1888
Total effect (A+B)		-0.0649	-0.0756	-0.1086	-0.1108

Note: The itemized effects and baseline effect are regarded as zero if significance level is lower than 0.9.

E. Discussion

The results from itemized scores are summarized as follows. Overall, green condominiums are traded at a discount. However, those having a long-life design and contributing the mitigation of heat-island phenomenon are associated with smaller price discounts. Those using eco-friendly materials, circulating water, providing more green areas, and having energy saving features are associated with greater price discounts. What is the reason for such different effects by item?

A leading explanation is based on future maintenance costs. If a feature of a condominium incurs higher costs in maintenance and replacement of equipments, the owner rationally discounts the initial transaction price by subtracting the present value of future costs.

A longer life should be associated with a higher sale price because owner's costs of maintenance and renovation are significantly lower. The long life is especially effective in Japan where condominiums have relatively short economic lives. The estimated half life of condominium units is about 20 years though not reported in the paper.

The use of eco-friendly materials can increase owner's maintenance costs. The durability of eco-friendly materials can be less than that of standard materials, and it can be uncertain. If buyers expect higher maintenance costs due to frequent replacements of more costly eco-friendly materials, initial transaction prices can be discounted.

The water circulation system also requires more costly maintenance. Additional machines and pipes need to be cleaned, fixed, and replaced more frequently. Similarly, the greening-related discount can also be understood by maintenance costs. A larger area with planting will cost owners for pruning and cleaning.

A puzzling result is for the energy saving. The energy saving equipments should lower the user cost of condominium owners, and thus it is more likely associated with positive effects. However, there are only 190 units, or 13% of total green units, that receive positive scores in this field. Given that energy saving equipments are adopted widely even for non-green condominiums, the energy saving criteria in the Tokyo Program may be too extreme. The required level of energy savings in the program may be exceeding the break-even point and resulting in a negative NPV.

Another possible explanation is based on the omitted variables bias due to unobservable quality differences. A condominium may be developed as a green building in order to mitigate some negative factors in location or developer characteristics. For example, if the development site is former industrial site around which few green open spaces exist, the developer may choose to make the project green in order to mitigate the unattractiveness of the site. Another example is about developer's negative characteristics. A less competitive or less creditworthy developer may choose to develop green condominiums in order to attract customers. Such less competitive developers may be associated with price discounts via some unobservable factors. If such a relation between unattractiveness and green developments systematically exists, the green indicator may pick up negative effects of such omitted negative characteristics.

On the first point on industrial sites, a massive amount of redevelopments of former industrial sites actually occurred during the sample period along newly opened Rinkai line in Koto ward. In our alalysis, we control for unobservable negative impacts of such developments by indicator variables for jurisdiction and railway line.

On the second point on developer characteristics, we do not have developer information on all condominiums, but we do have developer information on green condominiums. Based on casual investigations into names of developers of green condominium, we do not find systematic tendency that "low quality" developers develop green condominiums more frequently. Rather we frequently observe large and creditworthy developers. It seems more likely that developers of better quality are attenuating our negative estimates of the green effect.

V. Conclusion

We find that green buildings may well be associated with price discounts rather than premia. The value of green buildings critically depends on the definition of green buildings, institutional settings, policy package, and user's preferences. Therefore, a particular result for a certain property type in a jurisdiction or a country cannot be generalized without a condition. For example, price premia that are reported in previous studies are mainly based on energy efficient buildings. More empirical studies for different property types in different areas are necessary in order to understand the value of green buildings. Our list of extensions includes a study on commercial buildings in Tokyo, and studies for other cities in Japan.

We also find that different environmental items result in very different valuation. Each item is considered to have different effects in three dimensions; technological effects on costs, policy-oriented effects on costs, and user's valuation. Our findings indicate that positive effects through policy and preferences are still limited while increased technological costs are directly capitalized. We conclude that much stronger policy measures are called for in order to overcome the price discounts and even generate price premia for autonomous diffusion of green buildings.

Reference

Architectural Institute of Japan. 2000. Architectural Charter for a Global Environment. Tokyo, Japan.

California's Sustainable Building Task Force. 2003. The Costs and Financial Benefits of Green Buildings. Sacramento, California.

Eichholtz, Piet M. and Kok, Nils and Quigley, John M. 2010. Doing Well by Doing Good? Green Office Buildings. Forthcoming, American Economic Review.

Fuerst, Franz & McAllister, Patrick. 2008. Green Noise or Green Value? Measuring the Price Effects of Environmental Certification in Commercial Buildings. MPRA Paper 11446, University Library of Munich, Germany.

Miller, N., Spivey, J. & Florance, A. 2008. Does Green Pay Off? Unpublished Manuscript.

Pramerica Real Estate Investors. 2007. To Be Green or Not to Be Green? Why that is Not the Question?

RREEF. 2007. The Greening of U.S. Investment Real Estate – Market Fundamentals, Prospects and Opportunities.

RREEF. 2008. Globalization and Global Greening Trends in Green Real Estate Investment.

RREEF. 2009. How Green a Recession? – Sustainability Prospects in the US Real Estate Industry.

Rosen, Sherwin. 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition, Journal of Political Economy, Vol.82, pp34-55.

Yoshida, Jiro, John M. Quigley, and Chihiro Shimizu. 2010. The Effect of Green Building Label on Real Estate Prices: The Case of New

Condominiums in Japan. University of Tokyo CSIS Discussion Paper, No. 106.