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Economic returns to energy-efficient investments in the housing market: Evidence from Singapore[☆]

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ABSTRACT

Since January of 2005, 250 building projects in the City of Singapore have been awarded the Green Mark for energy efficiency and sustainability. This paper analyzes the private returns to these investments, evaluating the premium in asset values they command in the market. We analyze almost 37,000 transactions in the Singapore housing market to estimate the economic impact of the Green Mark program on Singapore's residential sector.

We adopt a two-stage research design; in the first stage, a hedonic pricing model is estimated based on transactions involving green and non-green residential units in 697 individual projects or estates. In the second stage, the fixed effects estimated for each project are regressed on the location attributes of the projects, as well as control variables for a Green Mark rating. Our results suggest that the economic returns to green building are substantial.

This is one of the first analyses of the economics of green building in the residential sector, and the only one analyzing property markets in Asia. Our results provide insight about the operation of the housing market in one country, but the policy implications about the economic returns to sustainable investments in the property market may have broader applications for emerging markets in Asia.

1. Introduction

In the past decade, systems for rating and evaluating the sustainability and energy efficiency of buildings have proliferated (Kotchen, 2006). In part, this reflects the potential importance of real property in matters of environmental conservation. For example, buildings and their associated construction activities account for almost a third of world greenhouse gas emissions. The construction and operation of buildings account for about forty percent of worldwide consumption of raw materials and energy. Thus, small increases in the "sustainability" of buildings, or more specifically in the energy efficiency of their construction, can have large effects on their current use of energy and on their life-cycle energy consumption. Projected trends in the urbanization of developing economies, particularly in Asia, suggest that the importance of energy efficiency in building will increase further in the coming decades (Costa and Kahn, 2009; Davis, 2009; Zheng et al., 2009, 2011).

In the U.S., two major programs have evolved to encourage the development of energy-efficient and sustainable buildings through systems of ratings to designate and publicize exemplary buildings. The government-sponsored Energy Star program began as a voluntary labeling program intended to identify and promote energy-efficient products. The Energy Star label was extended to new homes in 1993 and subsequently to commercial buildings. Buildings can receive an Energy Star certification if the source energy use of the building, as certified by a professional engineer, is below a specified benchmark level; the label is awarded to the top quarter of all comparable buildings, ranked in terms of energy efficiency.

In a parallel effort, the U.S. Green Building Council (USGBC), a private nonprofit organization, has developed the LEED green building rating system to encourage the "adoption of sustainable green building and development practices." The requirements for certification of LEED buildings are substantially more complex than those for the award of an Energy Star rating, and the certification process measures six distinct components of "sustainability," one of which is energy performance.

In the short time since these rating systems for buildings were developed in the U.S., analogous certification procedures have been developed in many other countries. For example, the "BREEAM" rating system is now widely diffused in the UK, and the "Greenstar" rating system for buildings has been adopted in Australia. Both the British and Australian rating systems have much in common with the LEED system in the U.S. A program to publicize exemplary buildings in Canada, called

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"BOMA-Best," has been launched, and the European Union is currently negotiating a common system for the certification of commercial and residential buildings.

In 2005 Singapore became the first Asian country to adopt a system of green labeling for newly constructed and rehabilitated buildings. The system, called "Green Mark," has been widely publicized in the city-state, and the award of Platinum, Gold Plus, Gold, and Certified plaques for exemplary buildings are regularly reported in the newspapers.

Despite the international diffusion of these rating systems, little is known about their impact on the choices of consumers and investors or about their impact on energy usage or carbon emissions. Moreover, the adoption of a global green rating system or certification program in the property sector may be greatly impeded by the lack of market evidence of financial benefits of going green, particularly from the investors' perspective. By now, there are a few studies of rating systems for commercial office buildings in the U.S. (e.g., Eichholtz et al., 2010, 2011; Kok et al., 2011; Fuerst and McAllister, 2011), but there is no systematic body of evidence for other countries. There is also no evidence at all about the effects of these certification programs on the housing market.

This paper analyzes the "Green Mark" program in Singapore, evaluating the effect of the program on the housing market, in particular, the consequences for the asset values of dwellings in multifamily housing projects. In Section 2 below, we describe the salient features of the "Green Mark" program and its history. In Section 3 we present a detailed analysis of the sales of 74,278 housing units in 1,439 projects. About four percent of these projects had earned a Green Mark label by June 2010. In Section 4, we summarize the evidence on the economic premium for Green Mark projects. *Ceteris paribus*, we find that Green Mark-labeled dwellings command a substantial premium in the Singapore housing market. Section 5 is a brief conclusion.

2. The Singapore green mark program and certification

The Singapore Green Mark program (GM), which evaluates buildings for their environmental impact and energy performance, was launched by Singapore's Building and Construction Authority (BCA) in January 2005. The program seeks to provide a comprehensive framework for assessing the overall environmental performance of new and existing buildings to promote sustainable design, construction, and operations practices in buildings.

The GM scheme covers a wide range of property sectors — commercial, residential, retail, industrial, hotel, institutional, office, park and public housing. Typically, the regulations and building codes differ between residential and non-residential buildings. The scheme provides incentives for developers and design teams to construct green, sustainable buildings which can promote energy savings, water savings, and healthier indoor environments, as well as the installation of more foliage and landscaping for their projects. For existing buildings, the GM scheme encourages building owners and operators to meet specified operational goals and to reduce adverse impacts of their buildings on the environment and the health of occupants over the building life cycle.

The label is marketed for its ability to reduce water and energy consumption, to improve indoor environmental quality and to reduce potential negative impacts on the environment. Importantly, the label also helps to recognize developers with strong commitments to corporate social responsibility. It also helps publicize achievements in environmental sustainability.

The GM Program has evolved over time in promoting environmental sustainability through a variety of other supply-side incentives. For example, in 2006 a S$ 20 million Green Mark Incentive Scheme for New Buildings was introduced, which offers direct cash incentives to selected developers, building owners and project consultants whose new developments achieve a Green Mark Gold or higher certification.

Building codes were amended in April 2008, imposing minimum standards on environmental sustainability for all new buildings, requiring that new construction be comparable to the Green Mark-certified level.

In 2009, a Green Building Master Plan was announced; it sets a goal of Green Mark certification in eighty percent of new and existing buildings by 2030. Other initiatives have been introduced in the past several years.

2.1. Application and assessment process

Developers, building owners and government agencies may apply to the BCA to register their interest in participating in the BCA Green Mark Scheme. Following that, the assessment process involves a briefing to the project team to clarify BCA Green Mark requirements and the certification process.

The actual assessment is carried out at a later stage to verify that the building meets the certification criteria. The assessment includes design and documentary reviews as well as site verification. Upon completion of this assessment, a letter of award is sent to the team.

2.2. The rating system

The assessment criteria cover the following key areas:

- Energy Efficiency
- Water Efficiency
- Environmental Protection
- Indoor Environmental Quality
- Other Green Features and Innovation

The Green Mark program rates the environmental attributes of a building based on a point score. Up to 120 points are awarded for incorporating conservation features which exceed standard practice. Depending on the score, the rating is categorized in four quality levels — Platinum (90 points or more), Gold Plus (85–90 points), Gold (75–85 points) and Certified (50–75 points). Detailed information on the scoring system is presented in Appendix 1.

After achieving certification, Green Mark buildings are required to be re-assessed every three years to maintain Green Mark status. Newly-constructed, newly-certified, and existing buildings are subsequently re-assessed under uniform criteria for existing buildings.

3. The data

As of June 2010, 250 building projects were awarded the Green Mark, of which 86 are residential housing estates. Thus, the names and addresses[1] of GM awarded projects are identified on lists released by BCA. As one residential project usually consists of several buildings, we matched the GM-rated residential project names and addresses to the most comprehensive source of real estate information for Singapore, as of June 2010.[2]

Public housing accounts for about eighty percent of the overall housing stock in the Singapore residential housing market. The private housing stock is dominated by non-landed property, i.e., condominium and apartment properties. (See Table 1). Because property characteristics are quite heterogeneous among different submarkets (see Phang and Wong, 1997; Sing et al., 2006), we concentrate on private condominiums and apartments in this analysis.

[1] In Singapore, each building corresponds to a unique postal code.

[2] The Urban Redevelopment Authority's Real Estate Information System (REALIS) provides information for residential, commercial and industry property market. Specifically, it includes Time Series — more than 1300 time series; Project Database — integrated information on each project, such as the approval status and the number of units launched and sold; Stock Database — allows users to customize their own stock and vacancy statistics; Transaction Database — contains records of caveats lodged at the Singapore Land Registry since 1995 for the residential, commercial and industrial sectors. The Transaction Database is updated fortnightly.

Table 1
Characteristics of private and public housing markets in Singapore.
Source: Sing et al., 2006.

Housing type	Average floor/ land area (m^2)	Average transaction price (S$)	Housing stock (as of 4Q03)	Market share (%)
Private housing market				
Detached house	1,314	4,927,479	9,915	0.97
Semi-detached house	340	1,440,098	20,628	2.01
Terraced house	208	1,052,364	36,549	3.56
Condominium	133	803,168	85,869	8.36
Apartment	125	743,830	57,973	5.65
Public housing market			815,633	79.45

Some 62 GM-rated residential projects (condominiums and apartments), including both new and existing properties were matched. Transactions for some of 18,296 dwelling units in those 62 GM-rated projects between January 2000 and June 2010 were identified. Besides price, the transaction records included unit size, floor level, tenure type, property type, transaction date, transaction type, property location, and whether the purchaser previously lived in a public or private dwelling unit.

For control purposes we also identified some 1,377 projects with 55,982 dwelling unit transactions in projects that were not GM-rated.

The sample consists of sales of some 74,278 multifamily dwelling units sold between January 2000 and June 2010. These units are in 1,439 different housing projects (condominium and apartment residential estates) across Singapore, of which 62 projects (with 18,296 dwelling unit transactions) are GM-rated, while 1,377 (with 55,982 dwelling unit transactions) are not GM-rated (NGM). Fig. 1 compares the annual average sales price per square meter in GM and NGM projects over the 2000–2010.

The figure shows that sales of GM-rated dwellings typically commanded a higher sale price than NGM dwellings. Fig. 2 reports the temporal variations in the fraction of GM-rated sales.

As indicated in Fig. 2, the proportion of GM sales reached a peak of over thirty-five percent of all sales in Q2 2007. Since Q1 2006, the fraction of GM-rated sales more-or-less fluctuates with the dynamics of the overall property market. Notably, the dramatic drop in the fraction of green unit sales since Q2 2009 arises because a great number of non-green private dwelling projects were undertaken following the financial crisis, as a part of Singapore's recovery stimulus. Yet, regardless of the percentage drop of green unit sales, the absolute size of green unit sales from 2009 onwards has increased.

For each dwelling unit that has been sold, we gathered as much information as we could about its hedonic characteristics. Data on some of the attributes measured in other studies in the US or Europe are hardly relevant to the Singapore context. For example, all private housing projects in Singapore have air conditioning, a garage, and a swimming pool; the climate makes fireplaces less important. Some attributes (e.g., the number of rooms and bathrooms) are simply unavailable, but since the size of rooms in residential housing projects in Singapore is quite standardized, we can measure the total area of each unit. Some other attributes may be more important in the Singapore context. For example, there is empirical evidence that a good view is greatly valued among Singaporeans (Yu et al., 2007). Accordingly, we expect the floor level to be positively related to sale price, other things being equal.[3]

Apart from structural attributes, we control for location by adding indicator variables for properties located in 55 different planning areas.[4] We also include indicator variables for the month and year of sale, from 2000 to 2010, to control for the broader economic environment.

Furthermore, we exploit information on the property type (condominium or apartment), the type of transaction (new-sale, re-sale or sub-sale), planning area, and the tenure type (freehold or leasehold). In addition, we also identify the type of purchaser — a buyer who already lives in a public housing unit provided by Singapore Government's Housing and Development Board (an “HDB” flat) and seeks to upgrade to private housing, a buyer from the private economy (who currently lives in a private dwelling unit), or else a first-time buyer ineligible for purchase of an HDB flat.[5]

Columns (1) to (3) in the first panel of Table 2 report a comparison of the mean values of the hedonic attributes in GM and NGM-rated residential projects. All dwelling sale prices are converted to constant 2000 dollar values.

On average, GM-rated buildings are of higher quality than NGM buildings. In particular, the likelihood that GM certified dwellings are on a higher floor level (greater than twenty) is twice that of NGM certified units. GM housing is larger in unit size than NGM by about thirteen square meters. Clearly, there exists a substantial difference in the average transaction prices and unit prices per square meter between GM and NGM-rated units, confirming some difference in quality or the existence of a price premium for GM housing. In terms of property type, both GM and NGM share a similar pattern: more than half of projects/dwelling units are condominiums. Over sixty percent of housing transactions in both groups consists of new units, reflecting the dominance of the primary private housing market over the resale market. More than sixty percent of dwelling sales occurred in the central region, which is consistent with land scarcity and the competition for land use in the center. The number of buyers who previously owned private housing units or first-time buyers ineligible for public housing criteria exceeds the buyers trading up from public (“HDB”) flats.

Our data show that most of the dwelling units sold in this sample are freehold in tenure, though its share in the GM group is smaller than that in the NGM group. Freehold tenure yields more secure property rights and longer occupancy terms to the owner than leasehold, making buyers willing to pay a price premium (Tu and Bao, 2009). We control for this potential impact on housing prices in the regressions reported below.

Within GM-rated dwelling units, about fifty-seven percent have been awarded the Green Mark Gold, twenty-one percent and nineteen percent of total GM-rated sales have the Green Mark Gold Plus and the Green Mark certification, respectively, leaving three percent of dwellings rated Platinum. Housing sales vary over time between 2000 and 2010. Twenty-two and twenty-five percent of sales took place in 2007 and 2009, respectively, which reflect the underlying property market cycle in Singapore.

We gathered information on the location and amenity characteristics of each of the 1,439 projects in the sample. For each of these projects (housing estates), we define a set of location and amenity variables. These take the value of one if the project is located within 300 m of an expressway (*Express*), a bus or MRT subway station (*Bus/MRT*), or a park (*Park*), respectively. Another variable, *Dist2Orch*, measures the distance in kilometers of each project to Orchard Road

[3] In Singapore where most of the population live in high-rise public housing, it has been documented that the willingness and adaptability to live at high floors has grown dramatically, especially for younger generation. There is also a consensus that high-rise buildings are a model of sustainable building (Corporation of London, 2002; Abel, 2003).

[4] Singapore is subdivided in various ways throughout its history for the purpose of local administration and urban planning. In the 1990s, the Urban Redevelopment Authority (URA) carved up the country into 55 planning areas. List of Singapore Planning Areas is available at http://www.ura.gov.sg/student/planning_areas.htm.

[5] In Singapore, those who are eligible for public housing provided by Housing & Development Board (HDB) receive a substantial government housing subsidy and favorable mortgage terms. Most Singaporeans live in public housing. The rest of the population, who in general belong to the upper end of the income distribution, live in private housing. As a result, the control for share of private buyers can be used as an instrument for household income and social status, not otherwise available in Singapore.

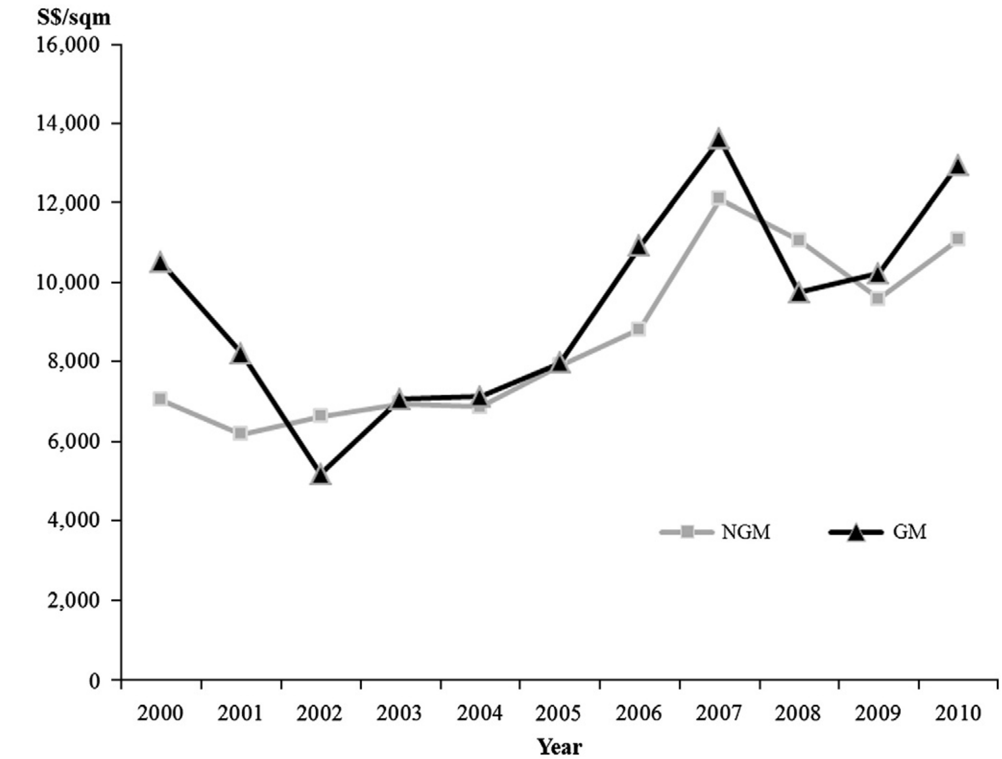

Fig. 1. Annual average unit price per square meter, 2000–2010.
(Data source: Singapore Urban Redevelopment Authority Real Estate Information System).

(the major shopping district). Since buyers from the private economy have higher incomes and greater wealth, on average, than citizens residing in government public housing (HDB), the proportion of new purchasers who come from the private economy may reflect (or help provide) a more desirable neighborhood environment for a given project. Thus, we recognize this by including the percentage of buyers

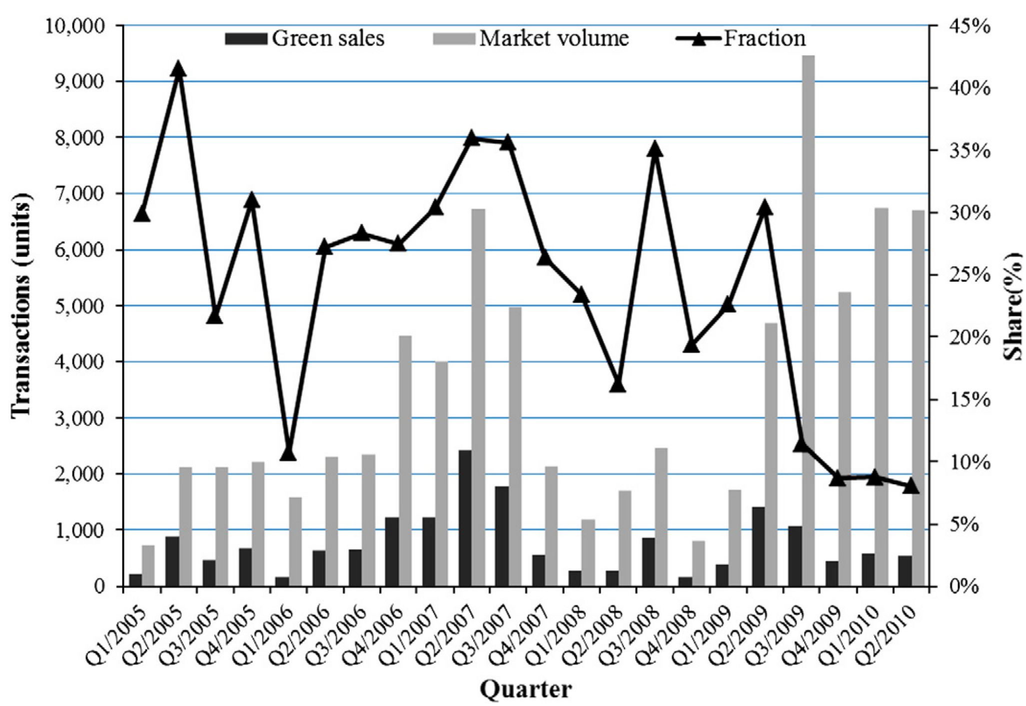

Fig. 2. Green fraction and trading volumes, 2005Q1–2010Q2.
(Data source: Singapore Urban Redevelopment Authority Real Estate Information System).

from the private economy for each project, *PrivateRatio*. We expect this variable to be positively associated with housing price.

The average values of these variables also differ substantially between GM and NGM properties. This is also presented in columns (1) to (3) in panel II of Table 2.

Our research design recognizes the distinction between attributes measured at these two levels: dwelling units and the projects in which they are situated. Note that this research design will also lead to quite conservative estimates of the importance of green certification on asset values. By design, all the co-variation between higher quality dwelling units and green certified properties is attributed to the dwelling units, not the environmental certification.

To control for the fact that the average characteristics of the GM and NGM samples are different, we employ Propensity Score Matching (PSM) techniques to weight the observations in the NGM group (control group) so that the control and treatment groups are more similar in terms of average characteristics.

Dwelling units sold in the NGM group are weighted according to their propensity scores, that is, the probabilities that their hedonic characteristics are identical to those in the GM group. (Black and Smith, 2004) We match on the basis of this scalar propensity score rather than matching on the basis of all housing characteristics (Rosenbaum and Rubin, 1983, 1984). Among the specific matching methods, we find that Nearest One-to-One Neighbor Matching is the best fit to our sample. It minimizes differences in the distributions between GM and NGM groups.[6]

Columns (4) and (5) in Table 2 present the mean values for GM and NGM groups weighted by their propensity scores. After matching, it is clear that the average values of the hedonic attributes of the NGM group are far closer to those of the GM group. For instance, prior to PSM, the average sizes for GM and NGM are 131 and 118 square meters, respectively; around seventy-three percent, twenty-one percent and seventy percent of GM-rated dwelling units are condominiums, on higher floors, purchased by private buyers, respectively, while only sixty-two percent, ten percent and sixty-six percent of NGM-rated dwelling units are condominiums, on high floors, purchased by private buyers. After nearest-neighbor matching, the matched GM and NGM-rated pairs have more similar average quality measures. The average sizes for GM and NGM are 131 and 126 square meters, respectively. Around seventy-three percent instead of sixty-two percent, seventeen percent instead of ten percent and sixty-nine percent rather than sixty-six percent of NGM group are condominiums, situated on high floors purchased by buyers from the private economy.

4. Empirical analysis

Our empirical analysis encompasses two estimation strategies. First, we adopt the most straightforward and conservative way to investigate the economic premium of Green Mark. In this approach, we simply relate the logarithm of unit sale price per square meter to a set of structural, spatial (e.g., floor area, floor level, tenure, property type, purchaser type, transaction type) and temporal control variables (e.g., transaction year, month of sale, and fixed effects for each of the 21 communities).

In the first stage, the logarithm of unit selling price per square foot is related to a set of structural variables — floor level, floor area, property type, tenure, construction type, transaction type, purchaser type, and spatial and time fixed effects, as well as a green indicator. In detail, given the satisfaction of living in high-rise building and appreciation of good view, building height is expected to positively relate to selling price; also, as condominiums are generally newer than apartments in design, we expect them to yield higher prices than other housing types. Freehold properties, yielding longer terms of occupancy and property rights, are anticipated to command higher values than leasehold properties. We expect that projects associated with larger fractions of private borrowers are more desirable.

$$logP_i = c + \beta X_i + \sum_{j=1}^{21} \gamma_j R_j + \sum_{k=1}^{10} \delta_k Y_k + \sum_{m=1}^{11} \phi_m M_m + \alpha g_i + \varepsilon_i \quad (1)$$

In Eq. (1), the dependent variable is the logarithm of the selling price per square meter P_i of transaction i. c is a constant and ε_i is an error term. X_i is a vector of hedonic characteristics of property i. To control further for regional differences, R_j, a community indicator is added, representing the planning area in Singapore in which each project is located. Y_k and M_m are year and month dummy indicators. β, γ_j, δ_k, ϕ_m are coefficients. exp (α) measures the price premium of a Green Mark certification.

$$logP_i = c + \beta X_i + \sum_{j=1}^{21} \gamma_j R_j + \sum_{k=1}^{10} \delta_k Y_k + \sum_{m=1}^{11} \phi_m M_l + \sum_{n=1}^{4} \alpha_n g_n + \varepsilon_i \quad (2)$$

Eq. (2) analyzes the four categories of the Green Mark premium: Platinum, Gold Plus, Gold and Certified.

The second approach adopts a two-stage hedonic pricing equation (Hanushek, 1974). In the first stage, we estimate a unit-level hedonic pricing equation similar to Eq. (1), except that we drop the project level variables, and we include instead project-specific fixed effects. The second stage considers the locational and amenity attributes measured at the project level, attributing all the covariation to dwelling characteristics. All dwellings in a given project have the same locational and environmental attributes.

$$logP_i = c + \beta X_i + \sum_{k=1}^{10} \delta_k Y_k + \sum_{m=1}^{11} \phi_m M_m + \sum_{q=1}^{696} \theta_q Proj_q + \varepsilon_i \quad (3)$$

Eq. (3) specifies the unit level hedonic model in the first stage. The essential difference of Eq. (3) from Eq. (1) is the inclusion of 696 project-fixed effects. Since the indicator variables for projects and communities are likely to be highly correlated, we drop the community variables, R_j, from Eq. (3). The estimated coefficient, θ_q, the project-specific fixed effect, is used as the dependent variable at the second stage hedonic equation.

In the second-stage hedonic equation, each of the project-fixed effects is related to the four project-level neighborhood variables: distance to Orchard Road, distance to the expressway, distance to the bus or MRT stop, and distance to parks. In addition, this equation relates each of the project-fixed effects to the fraction of private buyers for each housing projects. Because of the enhanced convenience and easy access to city center, a higher selling price is expected for dwellings closer to Orchard Road. Existing evidence of the impact of proximity to nearby amenities (expressway, bus or MRT, and park in this study) on property value is inconclusive and mixed[7], so we estimate the link between these neighborhood amenities and property values. As noted above, we expect that selling prices will increase with the number of competing buyers.

$$\hat{\theta}_i = c + \beta X_i + \sum_{j=1}^{21} \gamma_j R_j + \alpha g_i + \varepsilon_i, \quad (4)$$

In Eq. (4), the dependent variable, $\hat{\theta}_i$, the premium or discount for each project, is regressed on a set of accessibility variables. Here, c is a

[6] The key idea of One-to-One Nearest Neighbor Matching (NNM) is that for each unit sold in GM group we choose the dwelling in NGM group with the closest propensity score. We impose the common support restriction that units in GM group whose propensity scores are larger than the largest score in the NGM group are left unmatched. By doing so, we eventually manage to match 18,256 pairs of dwelling units, representing 697 projects in total.

[7] Hendon (1971), Wilhelmsson (2000).

Table 2
Comparison of GM and NGM-rated dwelling units (standard deviation in parenthesis).

	Overall (1)	GM-rated (2)	NGM-rated (3)	PSM GM-rated (1:1 nearest) (4)	PSM NGM-rated (1:1 nearest) (5)
Panel I: Units level hedonic characteristics					
Unit price/m^2 (S$)	10,206.06	11,049.44	9,930.43	11,050.31	10,543.35
	(5,237.81)	(6,063.97)	(4,906.65)	(6,070.27)	(5,889.90)
Unit size (m^2)	121.12	130.87	117.93	130.66	126.33
	(91.30)	(107.69)	(85.42)	(107.45)	(130.14)
Floor level (percent)					
Low (<10)	59.72	49.61	63.04	49.58	53.33
	(49.11)	(49.99)	(48.39)	(49.99)	(49.99)
Medium (10–20)	27.40	29.59	26.68	29.60	29.60
	(45.10)	(45.84)	(44.86)	(45.84)	(47.36)
High (>20)	12.88	20.80	10.28	20.83	17.07
	(32.71)	(40.63)	(29.32)	(40.63)	(35.49)
Freehold (percent)	57.80	34.63	65.37	34.68	45.69
	(49.91)	(47.69)	(49.26)	(47.70)	(49.34)
New construction (percent)	46.53	77.18	36.52	77.27	63.61
	(49.78)	(40.08)	(47.59)	(40.08)	(43.65)
Property type (percent)					
Condominium	64.72	73.30	61.92	73.37	72.63
	(46.95)	(42.77)	(47.85)	(42.78)	(42.48)
Apartment	35.28	26.70	38.08	26.63	27.37
	(46.95)	(42.77)	(47.85)	(42.78)	(42.48)
Transaction type (percent)					
New sale*	62.00	68.88	59.75	68.96	64.91
	(48.55)	(44.85)	(49.21)	(44.86)	(45.30)
Sub-sale**	16.46	21.00	14.98	21.00	20.98
	(36.02)	(39.22)	(34.90)	(39.23)	(31.71)
Resale***	21.54	10.12	25.27	10.04	14.11
	(41.9)	(28.49)	(44.38)	(28.50)	(37.99)
Purchaser type (percent)					
Private	66.79	69.79	65.81	69.76	69.01
	(47.95)	(46.22)	(48.37)	(46.23)	(47.24)
Public	33.21	30.21	34.19	30.24	30.99
	(47.95)	(46.22)	(48.37)	(46.23)	(47.24)
Location[a] (percent)					
Central region	70.67	63.90	72.88	63.83	66.55
	(48.05)	(48.09)	(48.04)	(48.09)	(49.03)
East region	17.84	13.96	19.11	13.99	17.41
	(35.81)	(33.26)	(36.52)	(33.27)	(35.57)
West region	6.75	11.17	5.31	11.19	10.88
	(34.40)	(32.41)	(34.97)	(32.41)	(38.01)
Northeast region	4.74	10.97	2.71	10.99	5.16
	(26.12)	(32.15)	(23.81)	(32.16)	(26.81)
Green Mark Award (percent)					
Platinum	0.76	3.07		3.07	
	(10.84)	(21.91)		(21.91)	
Gold Plus	5.11	20.74		20.78	
	(21.16)	(39.97)		(39.98)	
Gold	13.95	56.62		56.53	
	(34.07)	(49.51)		(49.52)	
Certified	4.82	19.57		19.62	
	(20.16)	(38.44)		(38.45)	
Transaction year (percent)					
2000	0.04	0.16	0.00	0.03	0.00
	(2.15)	(3.73)	(1.33)	(3.73)	(2.40)
2001	0.16	0.06	0.20	0.04	0.02
	(4.91)	(2.30)	(5.46)	(2.30)	(2.30)
2002	2.37	0.64	2.93	0.64	0.48
	(14.68)	(7.48)	(16.23)	(7.49)	(7.36)
2003	2.18	1.27	2.47	1.27	1.51
	(17.34)	(10.51)	(18.91)	(10.51)	(11.95)
2004	4.37	5.14	4.11	5.15	1.99
	(19.69)	(20.79)	(19.34)	(20.80)	(11.53)
2005	8.74	12.26	7.58	12.29	7.62
	(27.37)	(31.04)	(26.08)	(31.05)	(22.33)
2006	12.96	14.71	12.39	14.75	12.88
	(32.67)	(33.58)	(32.37)	(33.59)	(32.93)
2007	21.96	32.68	18.46	32.75	30.23
	(40.19)	(45.27)	(38.10)	(45.28)	(44.29)
2008	7.09	8.61	6.59	8.63	8.10
	(25.53)	(26.47)	(25.23)	(26.48)	(26.57)
2009	24.50	18.29	26.54	18.33	26.41
	(44.07)	(42.08)	(44.61)	(42.09)	(45.78)
2010	15.63	6.18	18.72	6.12	10.76
	(37.06)	(30.65)	(38.63)	(30.57)	(35.28)

(continued on next page)

Table 2 (*continued*)

	Overall (1)	GM-rated (2)	NGM-rated (3)	PSM GM-rated (1:1 nearest) (4)	PSM NGM-rated (1:1 nearest) (5)
No. of dwellings	74,278	18,296	55,982	18,256	18,256
Panel II: Project level accessibility and amenity characteristics					
Dist2Orch (kilometers)	6.48	4.31	6.57	4.31	5.49
	(37.03)	(3.63)	(37.76)	(3.63)	(3.91)
Express (percent)	13.54	17.74	13.37	17.74	15.75
	(34.22)	(38.51)	(34.04)	(38.51)	(36.45)
Bus/MRT (percent)	93.82	93.55	93.83	93.55	92.23
	(24.10)	(24.77)	(24.07)	(24.77)	(25.15)
Park (percent)	23.58	22.58	23.62	22.58	21.73
	(42.46)	(42.15)	(42.49)	(42.15)	(41.27)
Private ratio (percentage)	68.04	77.84	67.60	77.88	68.67
	(27.88)	(19.14)	(28.14)	(20.88)	(33.62)
No. of projects	1,439	62	1,377	62	635

Notes:

*New sale: the sale of a unit directly by a developer before the issuance of the Certificate of Statutory Completion and the Subsidiary Strata Certificates of Title or the Certificates of Title for all the units in the development.

**Sub-sale: the sale of a unit by an owner who has signed an agreement to purchase the unit from a developer or a subsequent purchaser before the issuance of the Certificate of Statutory Completion and the Subsidiary Strata Certificates of Title or the Certificates of Title or the Certificates of Title for all the units in the development.

***Resale: the sale of a unit by a developer or subsequent purchaser after the issuance of the Certificate of Singapore Completion and the Subsidiary Strata Certificates of Title or the Certificates of Title for all the units in the development.

[a] The four regions listed are Singapore planning regions: intended to facilitate the planning of the use and development of land (https://spring.ura.gov.sg/lad/ore/login/GLOSSARY.cfm?no=1#p).

Table 3
PSM regression estimation of unit price on dwelling units attributes (dependent variable: logarithm of unit price per square meter).

Variables	(1)	(2)	(3)
Green Mark (1 = Y)	0.0607***	0.0420***	
	(0.0039)	(0.0021)	
Platinum (1 = Y)			0.1434***
			(0.0138)
Gold Plus (1 = Y)			0.0227***
			(0.0036)
Gold (1 = Y)			0.0555***
			(0.0028)
Certified (1 = Y)			0.0081**
			(0.0036)
Size (m^2)	0.0003***	0.0001***	0.0001***
	(0.0001)	(0.0000)	(0.0000)
Floor level			
Low (1 = Y)	−0.0931***	−0.0431***	−0.0438***
	(0.0042)	(0.0025)	(0.0025)
High (1 = Y)	0.2188***	0.0892***	0.0871***
	(0.0056)	(0.0033)	(0.0033)
Condominium (1 = Y)	−0.2129***	0.0485***	0.0518***
	(0.0052)	(0.0031)	(0.0031)
Freehold (1 = Y)	0.1794***	0.0674***	0.0728***
	(0.0040)	(0.0026)	(0.0026)
New Construction (1 = Y)	0.0172***	0.0305***	0.0281***
	(0.0051)	(0.0031)	(0.0031)
Private Buyer (1 = Y)	0.2106***	0.0235***	0.0225***
	(0.0045)	(0.0022)	(0.0022)
Transaction type			
New-sale (1 = Y)	−0.0326***	0.0656***	0.0674***
	(0.0052)	(0.0029)	(0.0029)
Resale (1 = Y)	−0.1999***	−0.0705***	−0.0699***
	(0.0076)	(0.0042)	(0.004271)
Constant	9.2085***	8.7516***	8.7380***
	(0.0985)	(0.0901)	(0.0903)
Month dummy	Y	Y	Y
Year dummy	Y	Y	Y
Spatial fixed effects	N	Y	Y
Number of observations on dwellings	36,512	36,512	36,512
Adjusted R^2	0.4407	0.8354	0.8403

Notes:
All models are estimated by Ordinary Least Square (OLS) weighted by propensity scores. White Heteroskedasticity-consistent standard errors are reported in brackets and significance at 0.1, 0.05 and 0.01 level indicated by *, ** and ***, respectively. All models except for column (1) include spatial fixed effects (i.e., 21 planning area dummies) and time-fixed effects (e.g., 11-month and 10-year span).
Base purchaser type is ‘Public’; base dwelling type is ‘apartment’; base floor level is ‘medium level’; base sale type is ‘sub-sale’; base tenure type is ‘leasehold’.

constant and ε_i is an error term. X_i is a vector of locational attributes for project i, including distance to Orchard Road (*Dist2Orch*), closeness to bus stop or subway (*Bus/MRT*), access to expressway (*Express*) and closeness to park (*Park*). R_j, a community dummy variable, is used to control for the spatial variation among projects. The coefficient of primary interest is α, the economic price premium of Green Mark at the project level.

Table 3 presents the results of the hedonic model using 36,512 transactions in GM and NGM groups matched by propensity scores.

Table 4
Estimation of project fixed effects (dependent variable: project fixed effect).

Variables	(1)	(2)	(3)
Green Mark (1 = Y)	0.2112***	0.1453***	
	(0.0389)	(0.0281)	
Platinum (1 = Y)			0.2098
			(0.1400)
Gold Plus (1 = Y)			0.1504***
			(0.0562)
Gold (1 = Y)			0.1523***
			(0.0395)
Certified (1 = Y)			0.1008***
			(0.0330)
Neighborhood variables			
Dist2Orch (km)	−0.0668***	−0.0411***	−0.0410***
	(0.0030)	(0.0078)	(0.0079)
Express (1 = Y)	−0.0985***	−0.0438*	−0.0427*
	(0.0293)	(0.0247)	(0.0249)
Bus/MRT (1 = Y)	−0.2452***	−0.1069***	−0.1064***
	(0.0526)	(0.0397)	(0.0399)
Park (1 = Y)	0.0162	0.0370*	0.0364*
	(0.0263)	(0.0215)	(0.0216)
Private ratio (%)	0.2474***	0.1188***	0.1181***
	(0.0339)	(0.0276)	(0.0277)
Constant	0.6457***	0.239245	0.2446
	(0.0609)	(0.0839)	(0.0834)
Spatial fixed effects	N	Y	Y
Number of Observations on Projects	697	697	697
Adjusted R^2	0.5109	0.7049	0.7039

Notes:
Each regression is estimated with a sample of 697 GM and NGM projects matched by propensity scores. All models are estimated by Ordinary Least Square (OLS) in which White Heteroskedasticity-consistent standard errors are reported in brackets and significance at the 0.1, 0.05 and 0.01 level indicated by *, ** and ***, respectively. All regressions except for column (1) include spatial fixed effects (i.e., 21 planning area dummies).

Appendix 1. Point allocations — BCA green mark for residential buildings (version RB/3.0)

Category			Point allocations
(I) Energy related requirements			
Maximum cap of 50 points	Minimum 30 points	Part 1: Energy Efficiency	
		1-1 Building envelope — RETV	15
		1-2 Dwelling unit indoor comfort	16
		1-3 Natural ventilation in common areas	2
		1-4 Lighting	15
		Ventilation in carparks	8
		1-6 Lifts	2
		1-7 Energy-efficient features	7
		Category score for Part 1 — Energy efficiency (exclude bonus points)	65
Bonus 20 points		1-8 Renewable energy *(bonus points)*	20
(II) Other Green requirements			
Maximum cap of 50 points	Minimum 20 points	Part 2: Water efficiency	
		2-1 Water-efficient fittings	10
		2-2 Water usage	1
		2-3 Irrigation system	2
		Category score for Part 2 — Water efficiency	13
		Part 3: Environmental protection	
		3-1 Sustainable construction	12
		3-2 Greenery	6
		3-3 Environmental management practice	9
		3-4 Public transport accessibility	2
		Category score for Part 3 – Environmental protection	29
		Part 4: Indoor environmental quality	
		4-1 Noise level	1
		4-2 Indoor air pollutants	3
		4-3 Waste disposal	1
		4-4 Indoor air quality in wet areas	1
		Category score for Part 4 — Indoor environmental quality	6
		Part 5: Other Green features	
		5-1 Green features & innovations	7
		Category score tor Part 5 — Other Green features	7
Total points allocated:			120
Total points allocated (Include BONUS points):			140
Green Mark Score (Max):			100 + Bonus 20 points

(Source: Singapore Building and Construction Authority).

Appendix 2. Sample distribution across planning regions

Planning region	Dwelling units			Projects		
	GM	NGM	Total	GM	NGM	Total
Bedok	1,032	6629	7,661	2	223	225
Bukit Merah	925	2,343	3,268	2	26	28
Bukit Timah	320	4,151	4,471	3	114	117
Clementi	2,043	2,970	5,013	5	21	26
Downtown Core	2,523	1,754	4,277	3	11	14
Geylang	334	3,439	3,773	2	141	143
Hougang	1,314	1,356	2,670	2	67	69
Kallang	1,362	4,767	6,129	3	82	85
Marine Parade	427	4,260	4,687	3	99	102
Newton	121	1,674	1,795	3	62	65
Novena	1,174	5,249	6,423	5	159	164
Orchard	317	259	576	2	8	10
Pasir Ris	651	2,885	3,536	1	30	31
Queenstown	314	2,524	2,838	1	53	54
River Valley	514	3,057	3,571	6	73	79
Rochor	449	1,396	1,845	2	32	34
Sengkang	693	159	852	1	2	3
Singapore River	1,343	1,238	2,581	4	14	18
Southern Islands	554	737	1,291	3	6	9
Tampines	871	1,186	2,057	1	14	15
Tanglin	679	2,410	3,089	6	121	127
Toa Payoh	336	1,539	1,875	2	19	21
Total	18,296	55,982	74,278	62	1,377	1,439

Notes: The last planning region, Toa Payoh, serves as the reference group in regression.

For each model except for Column (1), community, month and year dummies are included, which are not reported separately in the table. Overall, housing attributes have the expected effects. We confirm the statistically significant value of a good view by noting the negative sign for the low level and the positive sign for the high level compared to medium level. Other housing characteristics, such as condominium dwelling type, new-sale, freehold tenure, and private purchasers, all consistently have anticipated positive effects on unit price. Although trivial in magnitude, larger dwelling units are likely to yield a slightly higher unit price than small size units.

In Model 1, the Green Mark price premium is statistically significant at the one percent level, indicating that Green Mark certification commands about a six percent premium over comparable, non-certified dwellings. Model 2 includes spatial fixed effects. The Green Mark price premium is estimated to be four percent, but the fitting of the model improves dramatically (R^2 improves from forty-seven percent in Model 1 to eighty-five percent in Model 2). Model 3 shows that the GM premium also varies significantly across different levels of certification: Platinum earns the highest return of fourteen percent; Gold earns a six percent price premium. The estimated coefficient of Gold Plus is smaller than that of the Gold award; nevertheless all Green Mark awards are statistically significant at five percent level.

Table 4 reports the results of the two-stage regression, the second stage regression at the project level.

The first stage estimation results (not reported here) are similar to those reported in Table 3. In the second stage regression, the estimated premium for each project, obtained from the first stage equation, is regressed on a set of property level location and amenity variables and spatial fixed effects (community dummy variables). In general, *ceteris paribus*, the average sale price increases with the share of private purchasers. Closeness to open space, *Park*, is statistically significant at the ten percent level with a positive effect on property value. The closeness to the bus or subway stop has a significant but negative impact on the price, which is consistent with the intuition that most of the private condo purchasers are less dependent on public transportation; they simply prefer privacy to easy access by mass transportation. Likewise, the closeness to an expressway is found to have a significantly negative impact of property value at ten percent level. Also, projects with less access to Orchard Road have lower selling prices.

The two-stage hedonic pricing model again suggests that all categories but Platinum of GM certified projects enjoy a statistically significant price premium compared to NGM rated projects, with magnitudes ranging from ten percent for GM Certified, fifteen percent for Gold and Gold Plus, and twenty-one percent for Platinum projects. On average, the Green Mark is estimated to yield a fifteen percent price premium on property value *ceteris paribus*, which is somewhat larger than the result reported in Table 3.

5. Conclusion

Our empirical analysis based on 697 individual projects and 36,512 transactions in the Singapore housing market suggests substantial economic returns to green building. The two-stage estimation shows that the Green Mark premium of four percent is statistically significant even after controlling for community amenities.

Of course, we cannot claim to have controlled completely for all differences in quality between GM and NGM dwellings. But we have measured and controlled for a large number of the hedonic characteristics of properties, including the characteristics and amenities of the neighborhoods in which they are located. We have also employed propensity matching techniques to control further for differences in the observed and unobserved characteristics of GM and NGM dwellings. Our nearest-neighbor research design is intended to be conservative as is our two step estimation procedure.

Based on nearest one-to-one neighbor matching between control and treatment samples, we find a significant premium in selling prices for dwellings with Green Mark Certification. The estimated premium is larger for dwellings certified at higher levels in the Green Market process — Platinum, Gold Plus, and Gold rated dwellings.

This is one of the first analyses of the economics of green building in the residential sector, and the only one analyzing property markets in Asia. Our results provide insight about the operation of the housing market in one country, but the policy implications about the economic returns to sustainable investments in the property market may have a broader application for emerging markets in Asia.

Appendix 3. Description of fixed effects coefficients and time trend

For month dummies: in Column 1 of Table 3, all 11 month dummies are significant at one percent level (December as base group); in Model 2, 10 month dummies are significant at one percent level with October statistically insignificant even at ten percent; Model 3 is the same as

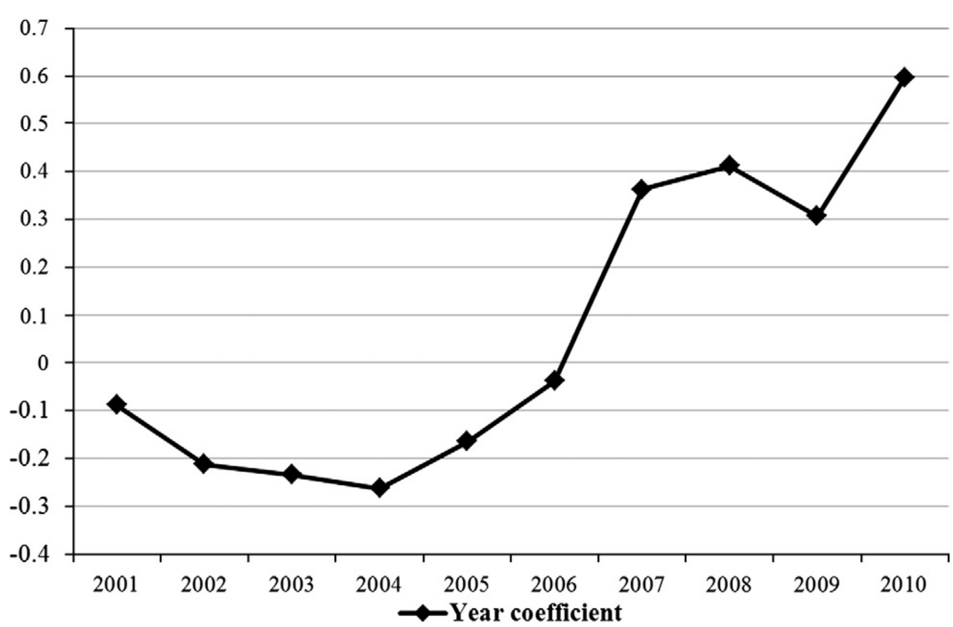

Fig. 3. Sale price tendency by year.

Model 2; For Year dummies: in Column 1, except for 2001 and 2009 (2000 as base group), all year dummies are statistically significant at one percent level; So are Model 2 and Model 3; For spatial fixed effects (planning areas): in both Models 2 and 3, only "Geylang" is statistically insignificant; for project-fixed effects: 409 out of 696 project fixed effects are statistically significant at ten percent level.

Based on the size of coefficients of year dummies over the sample period (all sales price standardized into 2000 dollar value), the trend presented in Fig. 3 above coincides with the selling price movement in Fig. 1.

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