Regional Science and Urban Economics 47 (2014) 35–44

Contents lists available at ScienceDirect

Regional Science and Urban Economics

journal homepage: www.elsevier.com/locate/regec

Economic returns to residential green building investment: The developers' perspective☆

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ARTICLE INFO

Article history:
Received 27 February 2013
Received in revised form 1 August 2013
Accepted 1 September 2013
Available online 21 October 2013

JEL classification:
Q2
R1
G3

Keywords:
Environmental sustainability
Green residential building
Singapore Green Mark system
Energy-efficiency investment
Financial performance

ABSTRACT

While many studies have shown that “green price premiums” accompany the development of green buildings, there is still significant doubt among the public as to the financial viability of investments in energy efficiency. In this paper, we examine this issue from the developers' perspective, and draw on data from Singapore's Green Mark (GM) system, which was introduced in 2005 to evaluate the sustainability and energy-efficiency of buildings. We find that the “green price premium” of residential developments arises largely during the resale phase, relative to the presale stage. The market premium of GM-rated units is about 10% at the resale stage, compared to about 4% during the presale stage. This implies that, while developers pay for almost all of the additional costs of energy efficiency during construction, they only share part of the benefits associated with such green investments. We also find no evidence that the development of green housing can immediately and significantly improve the corporate financial performance of Singaporean residential developers. These results provide the first evidence of the mismatch that developers face between outlays and benefits in the residential green building sector. This mismatch may impede further development of green residential properties. The emerging green real estate markets should be encouraged to introduce innovative business arrangements and financial products that allow residential developers to capture the future benefits associated with green properties.

1. Introduction

The development of green buildings has been gradually recognized as crucial for achieving the goal of a green society. The literature has documented that the construction and operation of buildings accounts for about 40% of the worldwide consumption of energy (see Deng et al., 2012, for example). This figure is especially critical in terms of electricity consumption: for example, in 2011, the commerce and service-related sector in Singapore consumed 37.5% of electrical output, while households consumed 15.7%.[1] Thus, improvements in the energy efficiency of buildings can significantly affect the amount of energy they consume over their life cycle.

At the same time, many members of the public are skeptical as to whether energy-efficiency investments for developing “green” buildings are financially sustainable. Following the pioneering work of Eichholtz et al. (2010), several recent empirical papers, using data from various countries, have found that energy-efficient properties can generate statistically significant positive “green price premia” in both their rental and sale markets (Fuerst and McAllister, 2011a, b; Brounen and Kok, 2011; Deng et al., 2012; Zheng et al., 2012; Eichholtz et al., 2013). Some of the earlier studies also suggest that the expected positive price premium is a key factor in explaining why green building development has been advancing rapidly during recent years in several major economies (Kok et al., 2011).

However, a positive price premium alone does not necessarily guarantee a positive economic return to developers or investors. Several papers have pointed out that the costs of building and maintaining energy-efficient buildings are also higher than those for conventional buildings, because of the costs of energy-saving facilities/equipment, eco-friendly materials, modeling integration, and management and consultancy fees (Gottfried, 2003; Circo, 2007). Therefore, an investment in energy-efficient real estate development can only be financially sustainable if the “green price premium” is large enough compared to the additional “green costs” to provide meaningful economic returns to investors.

☆ We are very grateful to two anonymous referees, Matthew Kahn, Jose Gomez-Ibanez, and participants at the Lincoln–Berkeley Conference on “Present & Retrospect: The Work of John M. Quigley” for valuable comments. We thank the Institute of Real Estate Studies at National University of Singapore for financial support. Wu also thanks the National Natural Science Foundation of China for financial support (No. 71003060). We gratefully acknowledge Zhiliang Li and Jia He for excellent research assistance.

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[1] Source: Energy Market Authority, Singapore.

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http://dx.doi.org/10.1016/j.regsciurbeco.2013.09.015

Accordingly, several recent papers look beyond the green price premium and seek more insights into the financial performance and economic returns of green building investments. Using US REITs as an example, Eichholtz et al. (2012) test whether the proportion of green properties in a REIT's portfolio affects its operating and stock performance. Their results suggest that REITs with a higher fraction of green properties perform better, in terms of their return on assets and return on equity ratios, and also have a lower beta. Similarly, Li and Deng (2012) investigate the effect of energy-efficiency investments on the financial performance of Singaporean commercial property holders. They find that property portfolios with a higher concentration of green properties do outperform the market, although the effect is only significant after 2007, when the Singapore government imposed more stringent environmental policies. McGrath (forthcoming) focuses on the effects of voluntary eco-certification on the excess capitalization rates (i.e., the reported capitalization rate less the risk-free rate) of US commercial office properties. He concludes that eco-certified buildings have significantly lower excess capitalization rates than their non-certified counterparts, which is consistent with the anticipated future gains related to a lower market risk.

While all these studies show a significant and positive return for green investors in the commercial real estate sector, such findings cannot necessarily be extended to the green residential sector. Due to the inefficiency of the housing market (Case and Shiller, 1989; Capozza and Seguin, 1996), the (expected) future benefits of energy-efficient techniques may not be immediately and fully capitalized in the transaction prices of the properties. Hence, financially feasible green building investments (i.e., where the green price premium is large enough to offset the additional green costs) may not be developed in the residential sector, because of the mismatch between the occurrence of costs and realization of benefits. This timing issue may not be crucial in the commercial real estate sector, since a commercial property holder typically owns and operates commercial properties for a relatively longer period, and thus has more opportunities to reap the benefits of any green investments it has made. However, in the residential sector, and especially in most Asian markets, built dwelling units are always sold to households immediately after they have been completed, or may be presold before they have been completed. This makes the lump-sum payment from household buyers the only opportunity for a developer to collect the rewards from any green building investments. This can lead to a potential mismatch in the timing of the costs and benefits for energy-efficiency investments in the residential property sector: if, for whatever reason, the green price premium is only fully revealed in the market after the units are already sold to households, the developers can only get at most a portion of the benefits associated with their energy-efficiency investments, while they still have to pay almost all the costs of such investments during the construction. Thus, even if a price premium for green dwelling units does exist in the market, its existence might not lead to developers obtaining any meaningful economic returns.

The effects of the misalignment between costs and benefits in residential developments have been documented in previous studies. For example, Zheng and Kahn (2008) provide empirical evidence that access to urban amenities in Beijing, China, has been capitalized into the price of newly-built home units, but not into the price of residential land parcels. This implies that, while local governments bear most of the costs of public amenities, the benefits of these amenities accrue mainly to developers, not local governments. The authors suggest that this misalignment of costs and benefits at least partially explains the lack of well-developed public amenities in most Chinese cities. If a similar misalignment exists in the domain of green housing development as discussed above, it could be one of the factors that are discouraging further development in this sector. Therefore, more comprehensive analyses of the economics of energy-efficient dwellings, especially from the perspective of housing developers, are needed.

In this paper, we focus on Singapore's residential housing market, where the Green Mark (GM) system for rating and evaluating the sustainability and energy efficiency of buildings was introduced in 2005.[2] During the sample period (from January 2000 to June 2010), 18,224 GM-rated residential units in 62 complexes were transacted. Using a similar procedure as Deng et al. (2012), we match the non-GM-rated units to GM-rated units using propensity-score matching procedures. Instead of only testing for the existence and magnitude of a green price premium in the whole market, we focus on estimating the difference in premiums between the presale and resale stages to examine whether there were any timing mismatches in terms of costs and benefits from the developers' perspective.

The results of the hedonic model, based on the matched sample, suggest that the green premium associated with GM-rated dwelling units exists and is statistically significant, but mainly arises out of the resale phase. At the presale stage, GM-rated units achieve transaction prices that are 4.1% higher than their non-GM-rated counterparts, while the premium reaches 9.9% at the resale stage. This gap is also supported by several robustness checks. In particular, the difference-in-difference analysis based on paired repeated-sales of transactions suggest that GM-rated units experience an abnormal appreciation of 2–3 percentage points upon completion, consistent with the finding of a higher green price premium at the resale stage.

We also explore plausible explanations, and hypothesize that two major factors are driving this phenomenon. The first explanation is based on information asymmetry in housing presale arrangements (Chau et al., 2007; Deng and Liu, 2009) and the learning process of households. At the presale stage, households are reluctant to fully trust the Green Mark evaluation, which is mainly based on design and document reviews.[3] They only perceive this classification as credible, and are willing to pay more, once such green units have been delivered and lived in, since they would then be able to verify the "green" claims by checking the electricity bills. Therefore, we can observe the magnitude of the green price premium increasing after the physical delivery of the housing units. The second explanation is driven by supply-side factors. Since GM-rated residential units only emerged in Singapore recently, their market share in the resale sector was much smaller compared to the presale market during the sample period (11.5% vs. 28.5%). Our empirical results indicate that the green price premium is negatively related to the market share of green dwelling units, which is consistent with the findings by Chegut et al. (forthcoming).

These results provide the first empirical evidence of the mismatch of costs and benefits for developers of green residences. We acknowledge that, without detailed information on the individual building-level marginal costs associated with energy-efficiency investments, we cannot directly and accurately calculate the cash flow and return indicators of energy-efficiency investments in green dwellings.[4] However, developers may be discouraged from further involvement in this sector because they may perceive that their inability to recoup more than a portion of the green price premium lowers their economic returns.

Our empirical test based on 21 listed housing developers further confirms these findings. Controlling for other factors, a proxy measure of how green developers' portfolios were, i.e., the ratio of GM-rated dwelling sales in firms' total housing sales, does not have a statistically significant relationship with firm performance (returns on equity or returns on asset) and is negatively related to their market values. Given the potential upward bias attributed to possible reverse causality,

[2] See Deng et al. (2012) for more details about Singapore's Green Mark labeling.

[3] See Yu and Tu (2011) and Deng et al. (2012) for more details about the evaluation process.

[4] Yu and Tu (2011), one of the few studies on the magnitude of green costs in Singapore, estimate that the Green Mark feature increases costs by about 3%. In China, where the condominium housing market is very similar to that in Singapore, the Ministry of Housing and Urban–Rural Development, in a 2010 survey of all green-labeled dwelling buildings, concluded an average green cost of 196 yuan per m^2, or 4.1% of the average price of a newly-built housing unit in the same year (Qiu, 2012).

the results provide some evidence that energy-efficiency investments cannot directly and significantly improve developers' financial performance, at least in the short run.

The findings of this study reveal an important dilemma for residential property developers, compared with their counterparts in the commercial property sector, which may become a major impediment in the further development of green residential properties. While residential property developers are expected to be able to capture more benefits from their green investments in the future when the Green Mark system is further developed, the real estate market should also be encouraged to introduce innovative business arrangements and financial products that allow green residential developers to capitalize the future benefit associated with the green properties via, for example, performance guarantees or green derivatives.

The paper proceeds as follows. The next section describes the housing transaction dataset in Singapore that will be used in the empirical tests. Section 3 empirically compares the magnitude of the green price premium associated with GM-rated units between the presale and resale stages, and provides some explanations for the differences. Section 4 directly tests the effect of energy-efficiency investments on the financial performance of housing developers in Singapore. Section 5 concludes.

2. Data

The Green Mark (GM) environmental certification program was introduced by Singapore's Building and Construction Authority (BCA) in January 2005. It had been awarded to 250 buildings by June 2010, out of which 86 were residential buildings (Deng et al., 2012). Instead of studying all 86 buildings, we narrow our sample for several reasons. First, the transaction prices of public housing, which accounts for about eighty percent of the overall housing stock in Singapore, are highly regulated by the government. Thus we focus on the private housing market only. Second, we exclude “landed housing complexes” (i.e., single family houses and attached houses) from the sample, and focus on condominium and apartment units only. A major reason is that the variables available in the database are not a reasonable reflection of all of the key hedonic attributes for landed complexes. Moreover, the condominium/apartment sector dominates Singapore's private residential market currently.[5] Finally, in some cases, more than one GM-rated building was located in the same housing complex.

Using these criteria, 62 GM-rated housing complexes are included in our sample. Taking advantage of the Real Estate Information System developed by Singapore's Urban Redevelopment Authority (URA), we accessed the full sample of micro-level housing transaction data in Singapore between January 2000 and June 2010. There were 18,224 transactions from these 62 GM-rated housing complexes in this period. We accessed the detailed information for each transaction, including transaction type (i.e., presale or resale),[6] transaction date, transaction price, and buyer type (i.e., whether the purchaser previously lived in a public or private dwelling unit). Major hedonic attributes are also available, including complex-level attributes, such as property type (i.e., condominium or apartment), property location, completion year, and tenure type, and unit-level attributes, such as unit size and floor level. During the sample period, there were also 55,893 transactions from 1375 non-GM-rated complexes in Singapore, including 40,938 presale transactions and 14,955 resale transactions. In total, the sample contains 74,117 transactions.

Panel A in Table 1 lists the distribution of the sample. Since all 62 GM-rated complexes were completed in or after 2005, most transactions involving green dwelling units were presale, instead of resale, transactions. There were 16,280 presale transactions (28.5% of all presale transactions) in the sample period, compared to 1944 resale transactions (11.5% of all resale transactions). This implies that the supply of energy-efficient properties was relatively larger in the presale sector, and as discussed later, we believe this is one of the reasons leading to the difference in green price premiums between the presale and resale stages. During the sample period the GM-rated resale transactions concentrated in the relatively “lower” categories of “Certified” and “Gold”, while no “Platinum” units were resold.

Table 1
Sample distribution.

		Presale	Resale	Sum
(A) Unmatched sample				
GM-rated	Certified	3044	535	3579
	Gold	9005	1263	10,268
	Goldplus	3673	146	3819
	Platinum	558	0	558
	Sub-total	16,280	1944	18,224
Non-GM-rated		40,938	14,955	55,893
Total		57,218	16,899	74,117
(B) Matched sample				
GM-rated	Certified	3044	535	3579
	Gold	9005	1263	10,268
	Goldplus	3673	146	3819
	Platinum	558	0	558
	Sub-total	16,280	1944	18,224
Non-GM-rated		15,575	1944	17,519
Total		31,855	3888	35,743

However, directly comparing the GM-rated and non-GM-rated units may be misleading. As pointed out by Deng et al. (2012), GM-rated and non-GM-rated residential complexes may also differ across other non-energy efficiency related aspects. This gap could also be responsible for the difference in transaction prices between GM-rated complexes (the treatment group) and non-GM-rated complexes (the control group) and not accounting for it will lead to a biased estimation of the green price premium. Therefore, we follow Eichholtz et al. (2012) and Deng et al. (2012) in matching GM-rated residential units with “similar” non-GM-rated units, so that the control and treatment groups are comparable in terms of non-energy efficiency related characteristics and any potential bias in the estimated green premium is mitigated.

To match the units, we use the Propensity Score Matching (PSM) procedures that have been widely adopted in the housing literature (Black and Smith, 2004; McMillen, 2008; Deng et al., 2012). Dwelling units sold in the non-GM-rated group are weighted according to their propensity scores, reflecting the probability that their (non-energy efficiency related) hedonic attributes are identical to units in the GM-rated group. We then match each unit in the GM-rated group with the unit in the non-GM-rated group that has the most similar propensity score (the “nearest one-to-one neighbor matching” criterion).[7] To facilitate the comparison between the presale and resale stages, the PSM procedures are applied to these two groups separately (that is, the presale GM-rated transactions are matched with presale non-GM-rated transactions, and the same is done for resale transactions). This procedure leads to the GM-rated units in our sample being matched with 17,519 non-GM-rated residential units, which forms the control group in the empirical analysis. The distribution of the matched sample is listed in Panel B of Table 1.

[5] See Sing et al. (2006) for additional information on Singapore's residential sector.

[6] In this research we define presale transactions as transactions that occurred before the completion and physical delivery of the building, and resale transactions as transactions that occurred after that.

[7] We also try some other matching criteria. For example, considering that locational attributes are widely believed to be the most important factor in determining housing prices, we choose to match GM-rated and non-GM-rated units in the same community (using the PSM procedures to match non-locational attributes). All of the empirical results are robust to these different methods of matching.

Table 2
Major statistics of key variables.

	GM-rated			Non-GM-rated (unmatched)			Non-GM-rated (matched)		
	Presale	Resale	Total	Presale	Resale	Total	Presale	Resale	Total
Unit size (100 m^2)	1.30	1.18	1.28	1.14	1.24	1.17	1.29	1.16	1.27
	(0.58)	(0.42)	(0.50)	(0.55)	(0.53)	(0.54)	(0.63)	(0.45)	(0.61)
Floor level (%)									
–Low (<10)	48.09	63.32	49.72	61.26	67.98	63.04	51.20	58.85	52.05
	(49.97)	(48.20)	(50.00)	(48.97)	(46.66)	(48.27)	(49.99)	(49.22)	(49.96)
–Medium (10–20)	30.49	22.53	29.64	27.43	24.56	26.67	30.96	25.51	30.36
	(46.03)	(41.79)	(45.67)	(44.62)	(44.62)	(44.22)	(46.23)	(43.61)	(45.98)
–High (>20)	21.42	14.15	20.65	11.31	7.46	10.29	17.84	15.64	17.60
	(41.03)	(34.86)	(40.48)	(31.67)	(26.28)	(30.38)	(38.29)	(36.33)	(38.08)
Ownership (%)									
–Freehold	35.72	25.57	34.64	70.10	52.36	65.35	53.82	42.08	52.51
	(47.92)	(43.63)	(47.58)	(45.78)	(49.94)	(47.59)	(49.86)	(49.38)	(49.94)
–99 years	57.86	55.97	57.65	24.35	43.59	29.50	39.64	46.71	40.42
	(49.38)	(49.66)	(49.41)	(42.92)	(49.59)	(45.60)	(48.92)	(49.90)	(49.08)
–999 years	6.43	18.47	7.71	5.55	4.05	5.15	6.54	11.21	7.06
	(24.52)	(38.81)	(26.68)	(22.90)	(19.72)	(22.11)	(24.73)	(31.56)	(25.62)
Property type (%)									
–Condominium	74.56	63.84	73.41	60.58	65.70	61.95	74.21	62.81	72.94
	(43.55)	(48.06)	(44.18)	(48.87)	(47.47)	(48.55)	(43.75)	(48.34)	(44.43)
–Apartment	25.44	36.16	26.59	39.42	34.30	38.05	25.79	37.19	27.06
	(43.55)	(48.06)	(44.18)	(48.87)	(47.47)	(48.55)	(43.75)	(48.34)	(44.43)
Purchaser type (%)									
–Private	69.80	68.83	69.70	60.58	69.09	65.77	70.93	67.54	70.55
	(45.91)	(46.33)	(45.96)	(48.87)	(46.21)	(47.45)	(45.41)	(46.83)	(45.58)
–Public	30.20	31.17	30.30	39.42	30.91	34.23	29.07	32.46	29.45
	(45.91)	(46.33)	(45.96)	(48.87)	(46.21)	(47.45)	(45.41)	(46.83)	(45.58)
Number of units in the complex	523.72	583.50	530.10	242.53	296.27	256.84	365.31	370.56	365.89
	(307.99)	(308.18)	(308.55)	(205.38)	(270.03)	(225.68)	(202.39)	(215.70)	(203.91)
Building age (year)	−2.48	2.09	−1.99	−2.41	8.25	0.44	−2.44	2.25	−1.92
	(1.24)	(2.60)	(2.02)	(1.34)	(8.04)	(6.39)	(1.27)	(2.24)	(2.04)

Note: standard deviations are in parenthesis.

Table 2 provides the major statistics in each category. The non-energy efficiency related characteristics of the GM-rated and non-GM-rated groups are similar after the matching procedures.[8] Fig. 1 depicts the annual average prices for GM-rated and the matched non-GM-rated units across both presale and resale transactions. While this figure provides a preliminary indication of the existence of the green price premium in both these two stages, we leave more definite conclusions till after the empirical analysis.[9]

3. Empirical analysis on the "green price premium"

3.1. Green price premiums in the presale and resale stages

We follow the empirical strategy adopted by most previous studies in this field and test the existence and magnitude of the "green price premium" associated with the GM-rated residential units by directly relating the units' sale prices to their Green Marks and a set of structural, spatial and temporal control variables using a hedonic model.

The hedonic model is specified as Eq. (1). The dependent variable is the logarithm of the transaction price (SG dollar per square meter) of transaction i sold in month t, P_{it}. As for the explanatory variables, our key interest is the coefficient of the Green Mark indicator ($GREEN_i$), which equals 1 for GM-rated units and 0 otherwise. The set of other hedonic attributes (X_i) include: 1) unit size, whose effect on transaction price is uncertain and can only be revealed via the empirical tests; 2) floor level: typically units on higher floors are more desirable in Singapore since they enjoy better views, and hence are expected to get higher prices; 3) ownership type: freehold units are expected to be more expensive than leasehold properties since they can provide longer term occupancy and property rights; 4) building type: public opinion in Singapore generally expects condominiums to achieve higher prices because of their newer designs, better equipment and better decor than apartments; 5) purchaser type: units sold to households from the private sector are always more desirable, since such households are more experienced in the private residential market (compared with purchasers living in public housing units previously); 6) transaction type: the transactions are grouped as new sales from developers to households (the default group), sub-sale transactions before completion, and resale transactions after units are completed and put into use, with the former two groups both in the presale stage; 7) the number of units included in the complex: while larger complexes have more facilities and services, higher density negatively affects price, making the overall effect uncertain; and 8) building age: building age is set as the length between the transaction year and the expected completion year for presale transactions, and the length between the transaction year and completion year for resale transactions. Controlling for other factors, unit transaction prices at the resale stage are expected to be negatively correlated with building age because of the vintage effect; however, the effect is uncertain for the presale stage. We also use a set of dummy variables (R_i) to indicate the 22 communities in Singapore to capture residential units' locational

[8] We also divide the sample into 22 locational subgroups and introduce them in the matching procedures. We do not report their descriptive statistics in Table 2 to save space, but they are available upon request.

[9] An interesting fact is that the average price of GM-rated units was lower than non-GM-rated units in 2008. This phenomenon disappears in the following analysis based on the hedonic model.

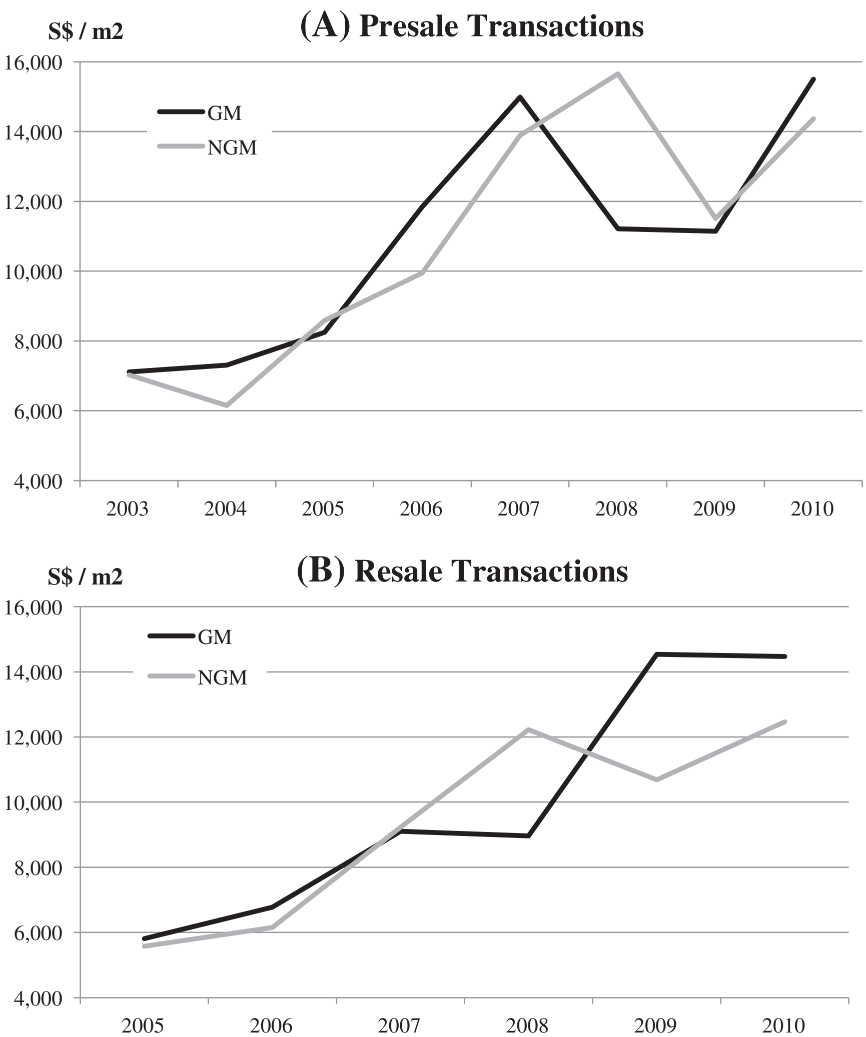

Fig. 1. Average transaction price of dwelling units.

attributes, and a set of time-fixed effects (D_t) on the 126 months (January 2000 to June 2010) to control for the effect of overall market conditions.[10]

$$\log P_{it} = c + \alpha \cdot GREEN_i + \beta \cdot X_i + \gamma \cdot R_i + \delta \cdot D_t + \varepsilon. \quad (1)$$

The model is estimated via OLS. Column (1) in Table 3 reports the results based on the full matched sample at both the presale and resale stages. The Green Mark indicator is positive and statistically significant in the model. According to the coefficient, controlling for other factors, the transaction price of a GM-rated residential unit is 4.7% higher than its comparable but non-GM-rated counterpart. This result is consistent with the previous estimation of a green premium of 4.2% by Deng et al. (2012) in Singapore market, and again confirms the existence of a substantial green premium associated with the Green Mark certification in Singapore. Moreover, the effects of the control variables are generally consistent with our expectations, with most of them statistically significant and the overall explanatory power of the model being 87%.

However, instead of the overall sample, the interest of this paper is the difference between the presale and resale stages, since only the green price premium at the presale stage can help developers obtain an economic return out of their investments in energy efficiency. First, in column (2), we introduce the interaction term between the Green Mark indicator and the dummy indicating the resale stage to the basic specification. The results suggest that the magnitude of the green premium is significantly larger in the resale stage compared to the presale stage. According to the coefficient, GM-rated residential units can command a green price premium of 9.9% during the resale stage, compared with a premium of 4.1% during the presale stage. We next split the sample into two parts – presale transactions (column (3)) and resale transactions (column (4)) – and re-estimated the basic specification for each of these two samples. The gap in the green premium is now even larger: controlling for other factors, the green premium that a resale residential unit can command reaches as high as 13.9%, while a presold GM-rated unit enjoys a price premium of 4.0%, or about one quarter of the premium at the resale stage.

In Table 4, we introduce more details about units' level of Green Mark certification (Certified, Gold and Platinum; we combine Gold and Gold-plus in the group of “Gold”) for a more in-depth investigation of the green price premium. Again, the results suggest the green price premium is significantly larger at the resale stage. As reported in Column (2), the interaction term between Green Mark certification and the resale dummy is significantly positive for Gold-rated residential units, and also positive (although statistically insignificant) for Certified-rated units. The gaps are even larger in estimations based on the split samples. According to the results in Column (3) and (4), the green

[10] We also try introducing a set of 2722 community–month interaction terms (22 communities ∗ 126 months), and the results are robust.

Table 3
The green price premium in the presale and resale stages (I).

	Dependent variable: log(transaction price)			
	Full sample		Presale	Resale
	(1)	(2)	(3)	(4)
GM-rated	0.046	0.040	0.039	0.130
	(22.02***)	(17.92***)	(17.11***)	(24.09***)
GM-rated * Resale	–	0.054	–	–
	–	(8.72***)	–	–
log(unit size	0.032	0.033	0.047	−0.144
(100 m²))	(11.24***)	(11.35***)	(15.36***)	(−19.37***)
Floor level (%)				
–Low (<10)	−0.043	−0.043	−0.043	−0.026
	(−18.32***)	(−18.47***)	(−17.39***)	(−4.43***)
–High (>20)	0.077	0.078	0.074	0.102
	(26.21***)	(26.30***)	(23.90***)	(13.19***)
Ownership (%)				
–99 years	−0.047	−0.047	−0.046	0.010
	(−14.16***)	(−14.18***)	(−13.17***)	(1.00)
–999 years	−0.065	−0.068	−0.083	−0.006
	(−14.72***)	(−15.28***)	(−16.64***)	(−0.53)
Property type (%)				
–Apartment	−0.060	−0.060	−0.059	−0.107
	(−18.02***)	(−18.09***)	(−16.65***)	(−12.40***)
Purchaser type (%)				
–Public	−0.019	−0.018	−0.020	−0.021
	(−8.26***)	(−8.19***)	(−8.05***)	(−4.44***)
Transaction type (%)				
–Sub-sale	−0.036	−0.037	−0.030	–
	(−12.54***)	(−12.91***)	(−9.41***)	–
–Resale	0.010	−0.018	–	–
	(1.89*)	(−3.05***)	–	–
log(number of units)	−0.015	−0.015	−0.017	−0.009
	(−7.76***)	(−8.09***)	(−8.22***)	(−1.97**)
Building age (year)	−0.032	−0.031	−0.035	−0.025
	(−37.12***)	(−36.61***)	(−29.69***)	(−18.11***)
Time-fixed effect	Yes	Yes	Yes	Yes
Locational-fixed effect	Yes	Yes	Yes	Yes
N	35,730	35,730	31,842	3888
R^2	0.866	0.866	0.865	0.924

Notes: *t*-statistics are reported in parentheses.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

Table 4
The green price premium in the presale and resale stages (II).

	Dependent variable: log(transaction price)			
	Full sample		Presale	Resale
	(1)	(2)	(3)	(4)
GM-rated				
–Certified	0.016	0.013	0.013	0.096
	(3.83***)	(2.89***)	(2.76***)	(10.76***)
–Certified * Resale	–	0.008	–	–
	–	(0.78)	–	–
–Gold	0.050	0.041	0.041	0.145
	(21.80***)	(17.04***)	(16.67***)	(23.34***)
–Gold * Resale	–	0.082	–	–
	–	(12.25***)	–	–
–Platinum	0.117	0.114	0.098	–
	(13.14***)	(12.81***)	(10.76***)	–
Control variables	Yes	Yes	Yes	Yes
Time-fixed effect	Yes	Yes	Yes	Yes
Locational-fixed effect	Yes	Yes	Yes	Yes
N	35,730	35,730	31,842	3888
R^2	0.866	0.867	0.866	0.925

Notes: (1) The control variables are consistent with Table 3.
(2) *t*-statistics are reported in parentheses.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

price premium is much larger at the resale stage for both the Certified- and Gold-rated units, although no Platinum-rated units were resold during the sample period.

This implies an economically important mismatch between the costs and benefits of energy-efficiency investments in the Singaporean housing market. While developers are burdened with the additional costs of using energy-efficient techniques, they can only obtain a portion of the corresponding benefits, as a substantial portion of the benefits are realized only after the developers sell the units to households. While we cannot conclude definitively whether a green price premium of 4% is large enough to generate a positive economic return without detailed building-level data on the green costs incurred, the timing mismatch at least makes energy-efficiency investments financially less feasible for residential developers, which, as we suggest earlier, may discourage the large-scale development of green housing.

As an interesting international comparison, the above pattern is diametrically opposite the findings of a previous study on the timing issue based on the nascent green housing market in Beijing, China (Zheng et al., 2012). The lack of a reliable and publicly accepted certification system on green buildings in China has led to developers of presale housing complexes in Beijing freely boasting about the “greenness” of their developments, even if such “green” techniques did not actually exist or were ineffective. This leads to many inexperienced households believing such advertisements and paying a substantial premium for such apartments. When the real energy efficiency

Table 5
Robustness checks.

	Full sample		Presale	Resale
	(1)	(2)	(3)	(4)
(A) Unmatched sample				
GM-rated	0.038	0.031	0.041	0.110
	(20.03***)	(15.55***)	(20.29***)	(19.81***)
GM-rated * Resale	–	0.059	–	–
	–	(11.81***)	–	–
N	73,259	73,259	57,094	16,165
R^2	0.836	0.837	0.851	0.811
(B) GM-rated complexes completed before 2010				
GM-rated	0.070	0.063	0.067	0.130
	(29.35***)	(24.46***)	(25.00***)	(24.09***)
GM-rated * Resale	–	0.045	–	–
	–	(8.18***)	–	–
N	27,151	27,151	23,263	3888
R^2	0.893	0.894	0.895	0.924
(C) Transactions in and after 2005				
GM-rated	0.064	0.053	0.057	0.130
	(25.79***)	(20.01***)	(20.21***)	(24.09***)
GM-rated * Resale	–	0.059	–	–
	–	(10.41***)	–	–
N	24,029	24,029	20,190	3888
R^2	0.891	0.891	0.892	0.924

Notes: (1) The control variables, and time- and locational-fixed effects are included in all models.
(2) *t*-statistics are reported in parentheses.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

Table 6
Difference-in-difference model based on repeated-sales.

	OLS	WLS
	(1)	(2)
GM-rated	0.031	0.025
	(5.05***)	(4.08***)
Time-fixed effect	Yes	Yes
N	4831	4831
R^2	0.782	0.793

Notes: t-statistics are reported in parentheses.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

Table 7
Explanations of the green price gap.

	Dependent variable: log(transaction price)			
	(1)	(2)	(3)	(4)
GM-rated	0.061	0.099	0.101	0.097
	(21.95***)	(18.10***)	(18.46***)	(12.68***)
GM-rated ∗ Building age	0.008	–	0.005	0.005
	(8.08***)	–	(5.38***)	(3.41***)
GM-rated ∗ Supply ratio	–	−0.198	−0.168	−0.162
	–	(−10.44***)	(−8.52***)	(−7.43***)
GM-rated ∗ Resale	–	–	–	0.007
	–	–	–	(0.72)
Control variables	Yes	Yes	Yes	Yes
Time-fixed effect	Yes	Yes	Yes	Yes
Locational-fixed effect	Yes	Yes	Yes	Yes
N	35,730	35,730	35,730	35,730
R^2	0.866	0.866	0.866	0.866

Notes: (1) The control variables are consistent with Table 3.
(2) t-statistics are reported in parentheses.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

performance of the apartment is revealed after the residential building complex is completed and residents receive their electricity bills, the units are actually resold and rented at a price discount. In other words, ironically, it may be easier for housing developers to boast the "green performance" of their complexes and thus get rewarded in a nascent green housing market without a trusted "green rating" system and where buyers are less experienced.

3.2. Robustness checks

As the key finding of the above empirical analysis, we address the difference in magnitude of green price premiums between the presale and resale stages. In this sub-section, we will test the robustness of these results.

First, we test whether the gap does result from the matching procedures. In Panel A of Table 5, we re-estimate the specifications in Table 3 based on the full sample of 74,117 transactions. This does not qualitatively change the findings; in particular, both the interaction term in Column (2) and the comparison between Column (3) and (4) suggest that the magnitude of the green price premium is substantially larger at the resale stage.

Second, the resale transactions of GM-rated dwelling units were mainly from the complexes that were completed relatively early on, and we should not be able to observe any resale transactions from GM-rated complexes completed after June 2010. If there are any unobserved attributes associated with GM-rated complexes completed earlier which could positively affect the transaction price, such omitted variable bias could lead to the gap we observe in Table 3. In order to test this factor, in Panel B, we exclude presale transactions from complexes completed in or after 2010 and re-estimate the specifications. It is true that the green price premium becomes larger in the presale stage, but the gap between these two stages is still significant, and the coefficient of the interaction term in Column (2) is almost unchanged compared with the coefficient in Table 3.

Similarly, considering that all the resale transactions occurred in or after 2005, while the presale transactions existed in all the years during the sample period, the gap we observe should be upward biased if the magnitude of the green price premium increased over time. Therefore in Panel C, we only include dwellings sold in or after 2005, and the results remain robust.[11]

We acknowledge that, even with the PSM procedures and the robustness checks above, it is practically impossible for us to rule out all the potential omitted variables that can affect the gap in green price premium between the presale and resale stages. Therefore, we further construct a sample of paired repeated-sales transactions and test the statistical significance of the gap in green price premium based on the difference-in-difference approach. We hypothesize that if the green price premium is significantly larger at the resale stage than the presale stage, we should observe an abnormal appreciation of GM-rated dwelling units upon completion; that is, controlling for other factors, GM-rated dwelling units should experience higher price growth after completion compared with their non-GM-rated counterparts. Compared with the cross-sectional analysis discussed above, this difference-in-difference analysis based on paired repeated-sales transactions can be reasonably expected to mitigate any potential bias due to omitted variables in our specifications.

For this purpose, we identify the repeated-sales transactions in the sample. During the sample period, there were 12,338 pairs of repeated sales in our sample.[12] Out of these, 4831 pairs comprise transactions before completion (i.e., at the presale stage) matched with transactions after completion (i.e., at the resale stage). There are 959 pairs from GM-rated complexes and 3872 pairs from non-GM-rated complexes in this set of repeat sales. Based on Eq. (1), with the assumption that the non-GM-rated attributes as well as their coefficients do not change upon completion, we arrive at this model for these 4831 pairs of repeated-sales transactions:

$$\begin{aligned} d\log P_{imn} &= \log P_{im} - \log P_{in} \\ &= (\alpha_{\text{after}} - \alpha_{\text{before}}) \cdot GREEN_i + \delta \cdot D'_{mn} + \varepsilon \\ &= \alpha' \cdot GREEN_i + \delta \cdot D'_{mn} + \varepsilon \end{aligned} \quad (2)$$

where: $d\log P_{imn}$ is the logarithmic change of price between two transactions, D'_{mn} is the set of time dummies to capture market conditions, which equal −1 in the period of the previous transaction, 1 in the period of the following transaction, and 0 otherwise; and $GREEN$ is a dummy for GM-rated dwelling units. Thus, the coefficient of α' captures the magnitude of abnormal appreciation upon completion associated with GM-rated units; in other words, it refers to the change in magnitude of the green price premium upon completion.

The results are listed in Table 6. Besides the regular OLS method, we also apply the standard Weighted Least Square (WLS) procedures developed by Case and Shiller (1989) to estimate the model. The coefficient of α' is positive and statistically significant via both methods. According to the results, GM-rated units experience an abnormal appreciation of 2–3 percentage points on completion, compared with their non-GM-rated counterparts, which is consistent with the results of the green price premium gap between the presale and resale stages.

[11] We also try running the specifications for each single year since 2005. The gap is significantly positive in all years but 2006, when it is positive and marginally significant.

[12] This is a huge number, considering that the overall sample size is 74,117, but not surprising since the private housing market of Singapore is well-known for investment/speculative activities and a high turnover rate. See Fu et al. (2012) for more details.

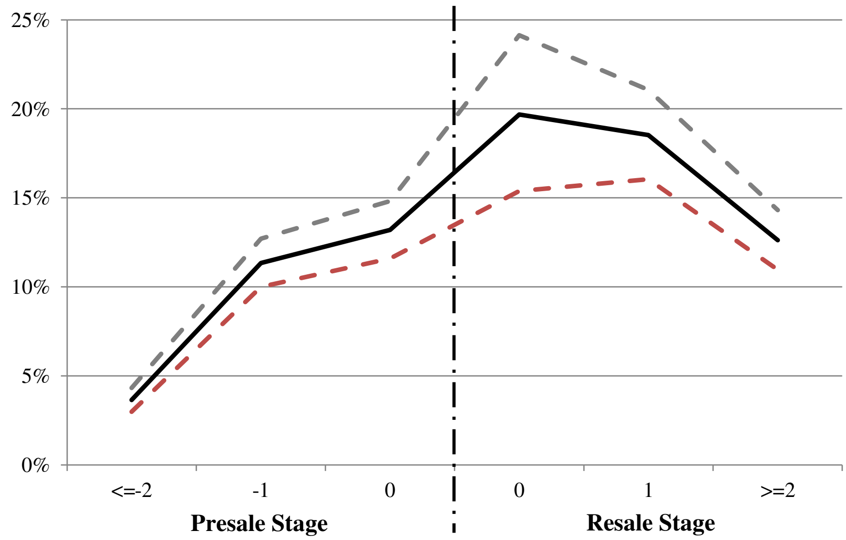

Fig. 2. Change of green price premium with building age.

3.3. Explanations of the green price gap

The results above naturally lead to the question as to why the green premium is substantially smaller at the presale stage compared with the resale stage. We believe at least two factors can explain this gap.

The first explanation comes from households' "learning process" in understanding and accepting the effectiveness of "green housing" techniques. Several prior studies have pointed out that information asymmetry is an important issue in presale housing transactions (Chau et al., 2007; Deng and Liu, 2009; Zheng et al., 2012). The assessment of energy-efficiency in presold complexes mainly relies on design and document reviews, since the complexes are still under construction and their energy-efficiency performance cannot be directly observed or measured. Although this evaluation system is carefully designed and should be expected to be reliable, it is natural for households to wait until they can directly observe the real performance themselves, for example, when the building is almost finished, or even when the buildings are completed and the electricity bills arrive.[13]

In order to test this explanation, we introduce an interaction term between building age and the Green Mark indicator to the basic specification in Table 3. As reported in Column (1) of Table 7, the magnitude of the green premium increases with building age, which serves as a proxy here of the length of period households have to understand the real performance of GM-rated dwelling units. We also estimate the basic specification for each building age group to test a potential non-linear relationship between building age and the green price premium. As depicted in Fig. 2, the green price premium is less than 5% for units presold 2 or more years before completion, but then gradually increases to about 10% when the building is almost ready and thus more information is available (i.e., 1 year or less before the completion). Once a building is completed, its green price premium jumps to more than 10% and stays around that level, although the premium drops two years after completion. This path is consistent with the explanation that households are willing to pay more when more information on the performance of the energy-efficient techniques is available.

We next analyze supply-side issues. Several papers have pointed out that, as basic microeconomic theories teach us, the magnitude of green price premium is negatively related to the supply of energy-efficient properties in the market (Chegut et al., forthcoming). As discussed above, GM-rated residential properties only emerged in Singapore after the Green Mark system was introduced in 2005. Thus, the housing stock in Singapore (i.e., the potential supply of the resale market) mainly consists of non-GM-rated units, and the proportion of GM-rated units was much smaller in the resale sector (11.5%) than in the presale sector (28.5%) during the sample period. In addition, dwelling units in the presale and resale sectors are not perfect substitutes: the key difference is that households can immediately move in if they purchase a resale unit, but need to wait for a substantial period if they purchase a unit from the presale market.[14] Therefore, the difference in market share of GM-rated units in these two sectors may at least partially lead to the gap in the green price premium.

In order to test this explanation, we introduce an interaction term between the Green Mark indicator and the market share of GM-rated units during the sample period (Column (2) of Table 7). To increase variance, we calculate the market share for both presale and resale sectors at the district level, which varies between 22.74% and 66.82% in the presale sector, and 8.73% and 31.92% in the resale sector. The interaction term is significantly negative in the model, which is consistent with the argument that the green price premium is larger in the sub-markets where there are fewer energy-efficient units. In Column (3), we introduce both the building age effect and the supply side effect into consideration, and the results remain robust.

According to the above analysis, at the presale stage households are reluctant to pay a high price premium for GM-rated housing complexes, since they are not able to directly observe the effectiveness of such green housing techniques before the buildings are completed. Instead, the energy-efficiency factor can only be fully capitalized in housing prices when the buildings are (almost) completed and put into use. Meanwhile, the supply of energy-efficient dwelling units has been relatively higher in the presale market during the sample period, which also results in a lower green price premium in the presale sector. In Column (4), we further introduce an interaction term between the

[13] Several studies have pointed out that the adoption of green building techniques does not necessarily lead to energy savings (Eichholtz et al., 2010; Zheng et al., 2012).

[14] During the sample period, the average length between transaction date and completion date for presold units was 2.40 years.

Table 8
Major statistics of key variables in the firm-level analysis.

	Average	Std. Dev.	Max.	Min.
ROE (%)	12.257	10.486	41.525	−10.667
ROA (%)	6.306	6.155	31.648	−4.895
TOBIN'S Q	1.084	0.315	0.570	2.500
RATIO_GREEN	0.085	0.220	0.000	1.051
ASSET (million US$)	4,412.921	5,103.776	24,698.260	267.055

Green Mark indicator and the resale stage dummy, which is no longer significantly positive in the model. This implies that these two factors explain at least most of the gap in the green premium between the presale and resale stages.

4. Green housing and developers' financial performance

The previous sections show that, while residential developers have to pay all the costs of energy-efficiency investments, they do not obtain all of the corresponding benefits when they presell such green dwelling units to households. This mismatch leads to the question whether developers that devote resources to green housing perform better.

For this purpose, we follow the empirical strategy of Eichholtz et al. (2012) and Li and Deng (2012). Again, we start from our (unmatched) database of residential transactions in Singapore as described in Section 2, and identify the presale complexes developed by 21 developers listed in Singapore, Hong Kong or elsewhere. We use these 21 listed firms in the following analyses, and obtain their key annual financial indicators between 2005 and 2010 from their annual financial reports.

Table 8 provides the definitions and major statistics of the variables. We use return-on-equity (*ROE*) and return-on-asset (*ROA*) as proxies of financial performance, and Tobin's Q (*TOBIN*) as a proxy for stock market performance. As for the explanatory variables, our major focus is the indicator measuring firms' efforts on energy-efficiency investments, *RATIO_GREEN*, which is defined as the ratio between a firm's sales of GM-rated dwelling units during a specific year (calculated based on the transaction sample) and its total sales of dwelling units in the same year (reported in its annual financial report). The average of the *RATIO_GREEN* indicator is 0.085, but this masks a substantial variance in firms' efforts in developing green housing complexes. On the one hand, the ratio equals 0 in 89 firm-years of all the 123 observations, including 13 developers that never developed any GM-rated dwelling complexes during the sample period. On the other hand, a few developers are heavily involved in green housing investments. There were three firm-years whose *RATIO_GREEN* reaches around 1.00,[15] which implies that almost all the dwelling units built by these firm(s) were GM-rated. We also include firms' total assets (*ASSET*) as a control variable, and introduce both year- and firm-fixed effects to capture other unobserved factors.

The results of the simple OLS regression are listed in Table 9. Controlling for other factors, *RATIO_GREEN* is insignificant in explaining both *ROA* (Column (1)) and *ROE* (Column (3)), and is negative in explaining Tobin's Q (Column (5)). The results are robust to introducing the lagged term of *RATIO_GREEN* instead (Column (2), (4) and (6)).

Naturally, these results should be interpreted with caution, given the very small sample size and the potential estimation bias. In particular, the results may be biased due to endogeneity or even reverse causality, since specific kinds of firms may be more likely to conduct energy-efficiency investments. However, as suggested by Eichholtz et al. (2012) and Li and Deng (2012), such bias always tend to overestimate the effects

[15] Since the numerator and denominator are collected from difference sources and cannot perfectly match (e.g., the sales of GM-rated units are reported in SG$ in our transaction database, while the total sales are reported in US$ in the financial report, and we make the conversion based on the average exchange rate in the corresponding year), the ratio may be slightly above 1 due to the measurement errors.

Table 9
Effect of energy-efficiency investments on corporate performance.

	ROA		*ROE*		Tobin's Q	
	(1)	(2)	(3)	(4)	(5)	(6)
RATIO_GREEN	1.655		−0.284		−0.121	
	(0.43)		(−0.12)		(−1.36)	
RATIO_GREEN(−1)		1.447		1.681		−0.194
		(0.34)		(0.62)		(−1.95*)
Log(*ASSET*)	0.225	1.672	0.062	0.549	−0.410	−0.588
	(0.06)	(0.32)	(0.03)	(0.17)	(4.27***)	(4.78***)
Firm-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	120	100	120	100	114	97
R^2	0.492	0.523	0.414	0.433	0.77	0.79

Notes: (1) *t*-statistics are reported in parentheses.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

of green investment on firms' performance, since typically more profitable developers are more likely to invest on green complexes, which is also supported by our tests (not reported here). Therefore, given that virtually any endogeneity-driven bias arising from our simple OLS specification is to raise the coefficient of green investment in Table 9 above its true value, the admittedly naive results here at least provide some evidence that green investments do not directly improve developers' financial performance (in the short run).

5. Conclusion

A sufficient economic return on energy-efficiency investments is crucial for the sustainable development of the green building industry. While the existing literature provides some encouraging results for the commercial property sector, the situation may be more difficult in the residential development sector: if a developer is unable to capture sufficient financial benefits from the lump-sum amounts transferred when it sells green dwelling units to households during the presale stage, it has lost the opportunity to share in the benefits during the resale stage.

Such concern is supported by the empirical results from this paper, based on the green residential property market in Singapore. While we observe a statistically significant green price premium associated with the Green Mark-rated dwelling units, consistent with Deng et al. (2012) findings, further investigation points out that the premium is realized largely during resale transactions, and is much smaller during the presale phase. Therefore, developers only reap part of the benefits from their energy-efficiency investments, and achieve a lower economic return. The naive analysis based on listed housing developers' financial reports also suggests that there is no evidence that the involvement in energy-efficiency investments significantly improves the financial performance of residential developers in Singapore.

This dilemma for housing developers may discourage them from further participating in future energy-efficiency investments. Optimistically, with the development of the Green Mark system, residential property developers in Singapore can be expected to be able to capture more benefits from their green investments in the future, when green building development is familiar to more market participants and made use of. In addition, investors and developers can also seek other channels that could help them maximize the benefits from the energy-efficiency investments. For example, developers of energy-efficient dwelling buildings can choose to provide some kind of performance guarantees during the presale stage, as often adopted by energy-services companies in the commercial real estate sector. Instead of preselling the units long before their expected completion, developers may also wait and sell green units when the buildings are almost ready, or even after the completion of the building. Alternatively, the developers may choose to hold and operate some units for a longer period. Furthermore, the real estate capital market should also be encouraged to introduce innovative financial products that allow green residential developers to capitalize the future benefits associated with green properties via green derivatives. Of course, most of these channels may well be associated with higher financial costs or additional learning costs, which should be covered in our agenda of future research.

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