THE IMPACT OF LEED-ENERGY STAR CERTIFIED OFFICE BUILDINGS ON THE MARKET VALUE OF ADJOINING BUILDINGS IN NEW YORK CITY

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ABSTRACT

Green building certification is a useful way to support objective evaluations of the sustainability of a building. Both the Leadership in Energy and Environmental Design (LEED) and Energy Star certifications are designed to reduce the negative environmental impacts of buildings and provide positive economic benefits to certified buildings. Given that a demonstrable positive economic impact is also required to satisfy one element of the triple bottom line of sustainability for these certifications, this study examined the economic impact of LEED and/or Energy Star certified office buildings on the market values of adjoining buildings in Manhattan, New York City (NYC), using a spatial analysis based on a Geographic Information System (GIS) and a statistical analysis utilizing R-Project. The study's findings reveal a positive impact for LEED and/or Energy Star certified office buildings on their adjoining buildings, pointing to the need for future research to investigate the spillover effect of LEED and/or Energy Star certified office buildings on other buildings in their neighborhood from a socio-economic standpoint.

KEYWORDS

LEED and/or Energy Star certified office building, market value, adjoining building

INTRODUCTION

The importance of sustainability has become widely recognized and is now a priority in many aspects of our daily lives. As a result, research in sustainability is no longer limited to economics, humanities, and the social sciences but has become a subject of interest to those working in fields such as environmental science and engineering. According to those seeking to diffuse a greater awareness of the importance of sustainability to the public (Kerstens et al. 2011; Lewin

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2012), a useful way to achieve this is to apply elements of the triple bottom line of sustainability (Spreckley 1981).

In order to stay abreast of the ever-changing demands of the marketplace, the construction industry is also transforming itself to improve performance in support of a more sustainable construction industry. Several developed countries have established green building certification systems to support efforts to evaluate the sustainability of green buildings as an important part of capital project sustainability initiatives, diffusing these certifications not only to their own construction industries but also those in developing countries (Eichholtz et al. 2010; Pearce et al. 2012; Chegut et al. 2013; Heinzle et al. 2013; Newell et al. 2014). Simultaneously, research into the economic impact of LEED or Energy Star certification on the property values of certified buildings continues apace, with researchers generally finding that property values tend to increase after green certification is achieved, rising above those of comparable buildings (Eichholtz et al. 2010; Miller et al. 2008; Fuerst and McAllister 2011).

The principle of supply and demand has been shown to also apply to appraised property values, which are affected by a number of internal or external features (Epley and Rabianski 1981; Epley et al. 2002; Loban and Jones 2008). This suggests that the impact of LEED and/or Energy Star certification might not only be a feature of the property commodity itself but could also play a role as an external feature for surrounding buildings when sales comparisons are performed from an economic standpoint. By identifying the impact of LEED and/or Energy Star certification on the property values of buildings that adjoin the certified building, this research investigated whether having a LEED and/or Energy Star certified building as a neighbor is indeed one of the external features that affect the property values of buildings adjoining LEED and/or Energy Star certified buildings by examining changes in market value over time. Our findings are expected to expand the concept of "green" beyond simple environmental performance to include critical economic factors related to green building certification that take into account not only environmental aspects but also how economic performance supports mutual economic growth.

BACKGROUND STUDIES AND LITERATURE REVIEW

Property values of LEED or Energy Star certified buildings

Previously, researchers have studied the impacts of both LEED and Energy Star certifications in terms of their effect on the property value of the building certified, reporting that both certifications have a positive economic impact on property values (Table 1).

Dermisi (2009) argued that not all levels of LEED certification have a positive impact on a building's property value; a particular level or version of LEED certification may have little or no positive impact on the economic value of a certified building, making it necessary to consider specific levels or versions of LEED certification in order to determine the precise economic impact of LEED certification on property values. Dermisi's in-depth study of the effect of various levels of both LEED and Energy Star certification found that although such certifications were generally beneficial, the assessed value for small buildings could be adversely affected by LEED-NC (new construction) certification at both the Silver and Certified levels, and the market value of small buildings was also adversely affected by LEED-NC certification at the Silver level. Other researchers have reported positive impacts of LEED and Energy Star certification for occupancy rates by rent (Eichholtz et al. 2010) and for rental and occupancy rates and sales price (Wiley et al. 2010), but in their study of Class A and B buildings, Fuerst

TABLE 1. Comparison of property values of LEED or Energy Star certified buildings and comparable non-certified buildings.

		Rental rates		Unit sales price		Occupancy rate		Resale value rate	
	Certification	C[1]	NC[2]	C	NC	C	NC	C	NC
Miller et al. (2008)	LEED	1.2–1.5	1			0.993–1.047	1	0.901	1
	Energy Star	1.05–1.09	1			1.01–1.035	1	1.053	1
McGraw-Hill Construction (2010)	LEED	1.01–1.06	1			1.025–1.064	1	1.068–1.109	1
	Energy Star	1.01–1.06	1			1.025–1.064	1	1.068–1.109	1
Wiley et al. (2010)	LEED	1.152–1.173	1			1.162–1.179	1		
	Energy Star	1.073–1.089	1			1.1–1.11	1		
Fuerst & McAllister (2011)	LEED	1.05	1	1.25	1				
	Energy Star	1.04	1	1.26	1				

[1]Certified
[2]Non-certified

and McAllister (2011) found that although LEED and Energy Star certification had a positive impact on rental rates they had a negative impact on several physical features not directly related to the LEED or Energy Star certification, namely building age and size; for sales price, certification had no positive effect but did negatively affect building size.

Chang and Chou (2010) examined the effect of a building's green design, which they included in the physical classification category, in their study of the economic benefits of green building design for urban real estate markets. They concluded that factors significantly associated with the project's greenness and the building's green space design all have a positive impact on not only the building's reputation but also the local urban real estate market.

The impact of changes in external environmental features on local property values

The property value of a building is affected not only by the property commodity itself but also by various features of the external environment (Friedman et al. 2013). Research into the effect of external environmental features on property values has shown that economic changes in property values occur in areas that have undergone a significant change in their neighborhood environment, with external environmental features that are directly related to the quality of human life having a pronounced economic impact on property market values in both the U.S. and countries in Asia. Studies of residential property values have found that urban forests and

greenness add value to parcels of land (Mansfield et al. 2005) and also benefit nearby properties generally (Saphores and Li 2012), while householders are willing to pay more for better environmental conditions in the form of sea views, greater accessibility and the superior air quality and lower noise levels typically found in a Green Belt (Hui et al. 2007). This works both ways, however; Lin et al. (2009) found that property values in residential neighborhoods were adversely affected by foreclosures. Commercial properties are not immune to such effects; better views and more space that is visible have also been shown to boost property values (Chun et al. 2011).

PROBLEM STATEMENT

The previous studies described above in the literature review examined the impact on the certified buildings themselves of LEED or Energy Star certification from an economic standpoint, concluding that the positive impacts achieved by a certification could be assessed in terms of the property values of the certified buildings using various economic measures (Miller et al. 2008; McGraw-Hill Construction 2010; Eichholtz et al. 2010; Wiley et al. 2010; Fuerst and McAllister 2011). These studies investigated ways of demonstrating that LEED or Energy Star certification supports sustainability based on the economic benefits gained by the certified building's stakeholders. However, the benefits gained by the adjoining buildings that surround a LEED and/or Energy Star certified building that are on the same block and share at least one common side zoning lot line have not previously been examined. As Chang and Chou (2010) pointed out, a local urban real estate market can benefit economically by the arrival of green buildings, so LEED and/or Energy Star certification could draw attention to a project's greenness, thus heightening its impact on the property market values of adjoining buildings. This research therefore sought to measure the economic benefits afforded to buildings adjoining a LEED and/or Energy Star certified office building in NYC in terms of the impact on their property market values. The findings of this research represent foundational research that will support efforts to understand the elements needed to accomplish one element of the triple bottom line of sustainability for LEED and/or Energy Star certification.

METHODOLOGY

Research area, data collection, and variables

To achieve its objectives, this research focused on a specific target area that was selected based on the following criteria:

- the availability of sufficient data on LEED and/or Energy certified buildings and of reliable and sufficient data on local property market values over time

NYC is a particularly active region for green building developments, including both LEED and Energy Star certified buildings as well as buildings with other certifications (Kaza et al. 2013). City planners developed PlaNYC to prepare the city to better suit the needs of its residents, encourage the local economy, address climate change issues, and improve the quality of life in NYC (The City of New York 2014). The US Green Building Council (USGBC) has reported that after the first city buildings received LEED certification in 2006, their total area began to increase rapidly from 2009 onwards. By 2012, NYC had the second highest number

of LEED certified buildings of any metropolitan area in the U.S., with approximately 80 percent located in Manhattan; that year the city was also ranked fourth among U.S. cities for the number of Energy Star certified buildings. At present, almost 90 percent of the city's LEED and/or Energy Star certified office buildings are located in Manhattan.

In order to ensure the accuracy and consistency of the data from various sources, the data sets directly related to LEED or Energy Star certification were collected from USGBC and the U.S. Environmental Protection Agency (USEPA), respectively, as these are the official organizations responsible for the certifications. The geographical information and characteristics of the LEED and/or Energy Star certified office buildings were provided by the Information Technology and Telecommunications Department (ITTD) of NYC and NYC's Department of City Planning (DCP).

The market value estimated by NYC's Department of Finance (DOF) can be taken as representing the property values for all properties in NYC. This data is consistently and transparently calculated and is expected to reflect actual market value differences across properties. Estimated market value data is produced and released annually and sufficient data sets are available for the purposes of this research. The market value estimated by NYC's DOF is the starting point for calculating the taxable assessed value of a property, and the city takes one of three approaches for estimating the market value, depending on the tax class, using annual actual property income and expenses or recent sales prices of comparable properties in the same neighborhood. The estimated market values may also be based on construction, replacement, or reproduction cost, or a combination of these factors to approximate the actual market value as closely as possible. As a result, the estimated market value is expected to sufficiently reflect changes in external environmental factors such as the economic recession in 2008 and thus provide an adequate fundamental property value for calculating the assessed value in this research (Almanzar 2012; New York City Department of Finance 2014).

Aydin et al. (2010), Matthews (2006) and Dermisi (2009) suggested that for the purposes of research, tax appraisals or assessor-generated property values should be utilized for the following reasons:

- The limited amount of data available on actual sales or transaction prices,
- The valid correlation identified between actual sales and tax appraisal values,
- Ease of comparison with the results of later research using the same type of data, and
- The advantages offered by the linkage of tax parcel GIS mapping data and other government data.

Cypher and Hansz (2003) and Kim and Son (2011) also concluded that an estimated market value will influence the market value judgments made by non-appraisers in the real estate market, while Zhang (2010) asserted that the tax base market value data offers a useful approximation to willingness to pay for a property. The use of actual sales prices in the form of a transaction price paid between sellers and buyers can be somewhat problematic due to the limited number of such transactions that take place each year and limited data accessibility: very few office buildings change hands each year and building owners are understandably reluctant to expose these transactions to public scrutiny. Therefore, the market value estimated by NYC's DOF provides an appropriate approximation of property market values in NYC for our purposes. In this research, market value data listed in NYC's DOF database for the fiscal years (FY) FY 2007 through FY 2015 were utilized for the analysis (Table 2).

TABLE 2. Research variables, measurements, numerical values assigned, and critical data sources.

Variable			Measurements and numerical values	Source
Independent	LEED	Level	No:0, Certified:1, Silver:2, Gold:3, Platinum:4	USGBC
		Coverage	No: 0, A partially certified building: 1, A fully certified building: 2	USGBC
		Certified year	Non-certified year:0, Certified year:1	USGBC
		Unit market value of certified buildings	Property market value from FY2007 through FY2013 is divided by the property area.	NYC's DOF
	Energy Star	Certified year	Non-certified year:0, Certified year: 1	USEPA
		Unit market value of certified buildings	Property market value from FY2007 through FY2013 is divided by the property area.	NYC's DOF
Dependent		Unit market value of adjoining buildings	Property market value from FY2007 through FY2013 is divided by the property area.	NYC's DOF

Defining the coverage and level of LEED certified office buildings that achieved multiple LEED certifications

An Energy Star certified building is required to renew its Energy Star certification annually by re-evaluating the results of its performance during the certification year. Energy Star certification is a binary process: either Energy Star certification is achieved or it is not. This means that although a building may achieve Energy Star certification in one year, it may be disqualified and lose its Energy Star certification the following year. In contrast, it is not necessary to reevaluate the building performance annually once a building becomes a LEED certified building. LEED certification is more nuanced and is expressed in terms of two major characteristics: the coverage of the LEED certification (i.e., whether the LEED certification is for the whole building or is limited to particular floors of the building) and the LEED certification level (ranging from Certified up to the highest level of Platinum). The buildings in this study included twelve LEED certified office buildings with multiple LEED certifications; we therefore sought to include the redefinition of the coverage and the level of LEED certified office buildings as additional LEED certifications were achieved. LEED certification for a whole building took precedence over LEED certification for one or more floors of a building for the LEED certification coverage, and a higher level of LEED certification was given priority when defining a building's LEED certification level for this study. In addition, the level of LEED certification should be redefined in accordance with the coverage of the LEED certified office building because a LEED certification for the whole office building might impact on the entire building's economic value; however, a LEED certification with the highest level of LEED certification may have less impact on the building's economic value. Of the 12 buildings that achieved multiple LEED certifications, 10 achieved two, 1 achieved three and 1 achieved four certifications; only one of these 12 buildings did not also achieve Energy Star certification during the research period. Table 3

lists the kind of coverage and its levels for each of the twelve LEED certified office buildings in the study and shows how they were defined for the purposes of this research.

Research Approach

Two different approaches were utilized in this research: spatial and statistical analyses. GIS was used to identify the spatial distribution of the LEED and/or Energy Star certified buildings and their adjoining buildings, as well as to integrate all the information provided by the various databases using a geographical map. A statistical analysis was then performed to test the correlation between the independent variables and the dependent variable and determine the direction and strength of the correlations between each pair.

TABLE 3. The coverage and the level of LEED certification for the 12 office buildings that achieved multiple LEED certifications and the definition of the coverage and level used for each LEED certified office building.

LEED certifications								Defining the coverage and level of LEED certified office bldg.
1st	Full[1]/ Certified	2nd	Partial[2]/ Gold	3rd	—	4th	—	Full/ Certified
1st	Full/Silver	2nd	Full/Gold	3rd	—	4th	—	Full/Gold
1st	Partial/Gold	2nd	Full/Silver	3rd	—	4th	—	Full/Silver
1st	Full/ Certified	2nd	Full/Gold	3rd	—	4th	—	Full/Gold
1st	Full/Silver	2nd	Partial/ Gold	3rd	—	4th	—	Full/Silver
1st	Full/Silver	2nd	Partial/ Gold	3rd	—	4th	—	Full/Silver
1st	Full/Gold	2nd	Full/Gold	3rd	—	4th	—	Full/Gold
1st	Partial/Gold	2nd	Full/Silver	3rd	—	4th	—	Full/Silver
1st	Full/Silver	2nd	Partial/ Gold	3rd	—	4th	—	Full/Silver
1st	Full/Silver	2nd	Partial/ Gold	3rd	—	4th	—	Full/Silver
1st	Full/Gold	2nd	Partial/ Platinum	3rd	Partial/ Platinum	4th	—	Full/Gold
1st	Partial/ Silver	2nd	Full/Gold	3rd	Partial/ Platinum	4th	Partial/ Platinum	Full/Gold

[1]LEED certification for the whole building
[2]LEED certification for the particular floors of the building

Geographical analysis approach. A geographical analysis was used to establish the geographic characteristics of the LEED and/or Energy Star certified office buildings and their adjoining buildings and increase the accuracy of the geographic information for all the buildings. This approach was also a fundamental process for the following statistical approach through integrating all the primary data sets and then constructing the data sheets required for the statistical analysis (Son et al 2012).

Statistical analysis approach. This research utilized two complementary regression models for the regression analysis, the hedonic price model and the Linear Mixed Effect Model (LMEM). The results of this statistical approach indicated the strength and direction of the impact of LEED and/or Energy Star certified office buildings on the market values of adjoining buildings through the values of the coefficients obtained for each independent variable. The hedonic price model generally utilizes measures of social capital or the value of the environment. This model is based on empirical studies and therefore had to be separated from non-environmental elements to include only the environmental elements when measuring the value of the environment using cross sectional data for land prices as a theoretical frame. As Can (1992), Kim and Son (2011), and Gibbons et al. (2014) pointed out, the hedonic price model is commonly used to measure the neighborhood effect as it encompasses characteristics of both the socio-economic and physical make-up of the local area in a heterogeneous market. Lee et al. (2009) also considered the hedonic price model to be a useful methodology for understanding the effect of surrounding environmental conditions on the rental rates for office buildings. Moreover, Newell et al. (2014) identified the percentage premiums achieved by green rating systems in Australia based on the regression coefficients found for their hedonic regression model. As a result of this consensus, the hedonic price model has generally been utilized to measure the value of mixed residential and commercial use properties in previous studies (Hough and Kratz 1983; Fisher et al. 1994). Depending on the type of transformation applied to the data sets used for the response variable and explanatory variables, the hedonic price model provides four equations with the following forms: linear, log-linear, semi-log, and log-log. Based on the type of data involved, the log-log equation was deemed most appropriate for this research and the following log-log equation for the hedonic price model applied:

$$\text{Log-log function: } \log(pi) = a_0 + a_1\log(z_1) + \ldots + a_n\log(z_n) + \varepsilon_i$$

Note. p_i: a value of response variable, a_p: coefficient, z_p: explanatory variables, ε_i: an error term, where $i = \{1,\ldots, n\}$ and n is the number of subjects in the data.

Used in isolation, the hedonic price model is not sufficient to analyze the full impact of a LEED or/and Energy Star certified office building on the unit market value of adjoining buildings over time because the model focuses on a particular point of time for its analysis of the effect of external environmental factors or features on market values. For this reason, LMEM was also utilized for the current longitudinal investigation of the changes in the market values of buildings in NYC that are located next to LEED and/or Energy Star certified office buildings. LMEM includes the fixed effects of explanatory variables on the response as well as random effects that vary depending on the subjects or the groups concerned. This statistical model is widely used for repeated measure data or cross-sectional studies in diverse research disciplines as it makes it possible for researchers to infer the primary object of interest by examining the fixed effects (Song 1999; Seltman 2014).

FINDINGS

Results of geographical analysis

Most of the 171 LEED and/or Energy Star certified office buildings in Manhattan are located in the midtown area, with the remainder being located in the southwest along the shoreline. Lower Manhattan and Midtown Manhattan are one of the most economically powerful areas in the world, with numerous international or national governmental organizations such as major banks and the Qatar Financial District. 130 LEED and/or Energy Star certified office buildings were selected as a screened population group for this study, and the selected certified building are presented in Figure 1. The LEED and/or Energy Star certified office buildings were sorted and selected by matching the Borough-Block-Lot (BBL) number that identifies a parcel of real estate property in NYC and is one type of geographic features in The Property Address Directory (PAD) for each member of the screened population group (Mayer-Schonberger and Cukier 2013). As NYC's DOF provides the market value for individual units in multi-residential condominium buildings rather than for entire multi-residential condominium buildings, those LEED and/or Energy Star certified office buildings with condominium buildings as one or more of their adjoining buildings were not included in the study. LEED and/or Energy Star certified office buildings with no adjoining buildings on the same block, thus occupying an entire city block by themselves, were also excluded. 274 buildings were identified as adjoining the 130 LEED and/or Energy Star certified office buildings included in the study. Of these, 20 buildings adjoined the 11 buildings with only LEED certification, 160 adjoined the 78 buildings with only Energy Star certification, and 94 adjoined the 41 buildings with both certifications. Several of the 274 adjoining buildings identified had at least two LEED and/or Energy Star certified office buildings as neighbors, as in the example shown in Figure 2. Adjoining buildings with two or more counterparts were counted separately for each counterpart for the purposes of this research.

Three LEED certified office buildings achieved two LEED certifications for the whole building. Two of these sought to enhance the level of their LEED certification from Silver to Gold and from Certified to Gold without changing the version of their LEED certification. The other certified office building re-achieved LEED certification to change its LEED certification from LEED-EB 2.0 to LEED-EB 2009 without enhancing the level of LEED certification. In general, the office buildings achieving multiple LEED certifications tended to achieve the higher level of LEED certification for a part of building or to increase the coverage of their LEED certification from just part of building to the whole building. Figure 3 presents the distribution of the buildings adjoining the selected LEED and/or Energy Star certified office buildings.

Results of the statistical analysis

Based on the results of the geographical analysis, all information on both the dependent variable and the independent variables was exported for the statistical analysis.

Descriptive analysis

The descriptive results show the trend in the unit market values for each type of building over time for the years 2007 through 2013. The median unit market values for each year were generally similar to or lower than the mean market values except in 2011 for LEED only certified office buildings, hence the shape of the data distribution was positively skewed and the median value and the mean values of adjoining buildings gradually increased over time (Figure 4). The

FIGURE 1. LEED and/or Energy Star certified office buildings in Manhattan, NYC.

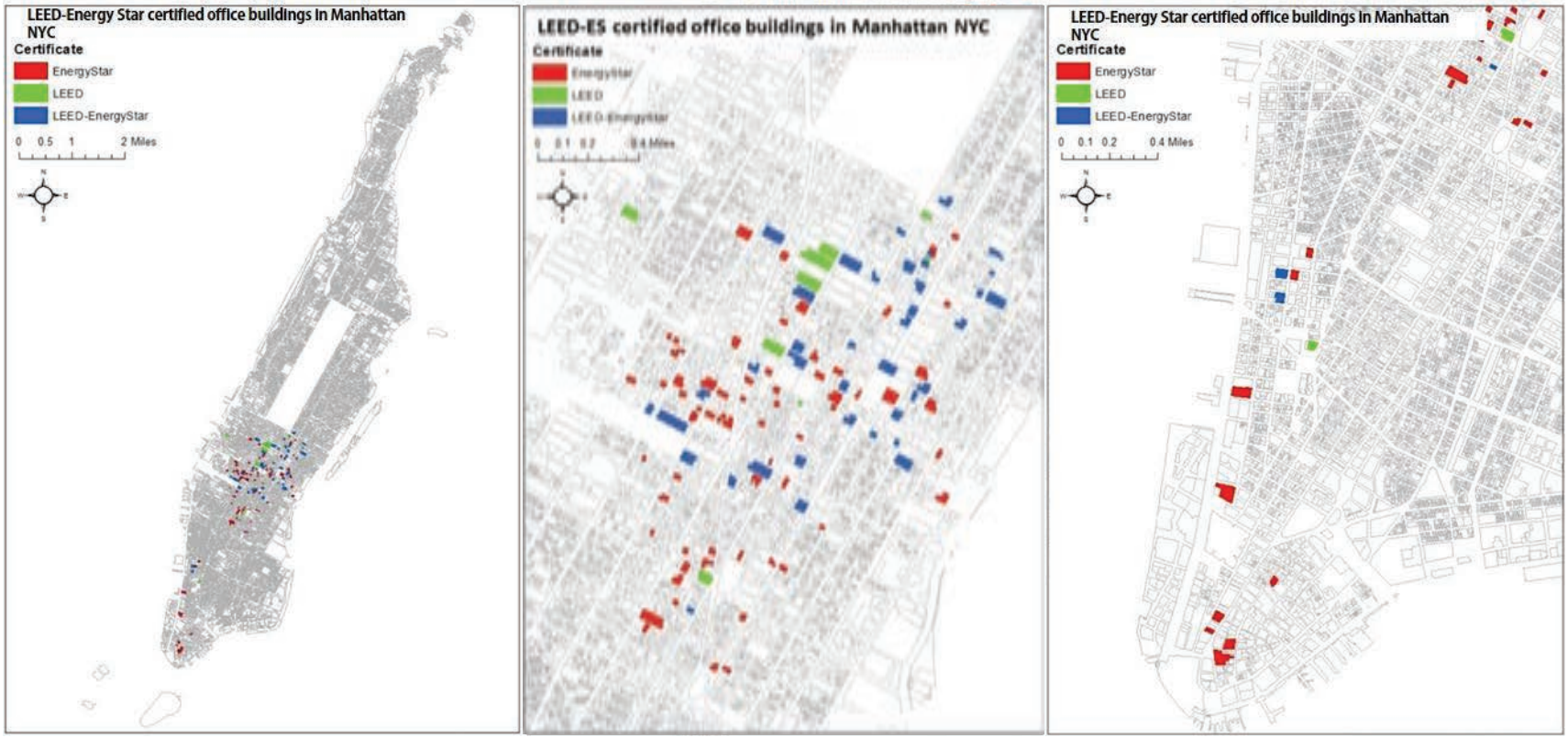
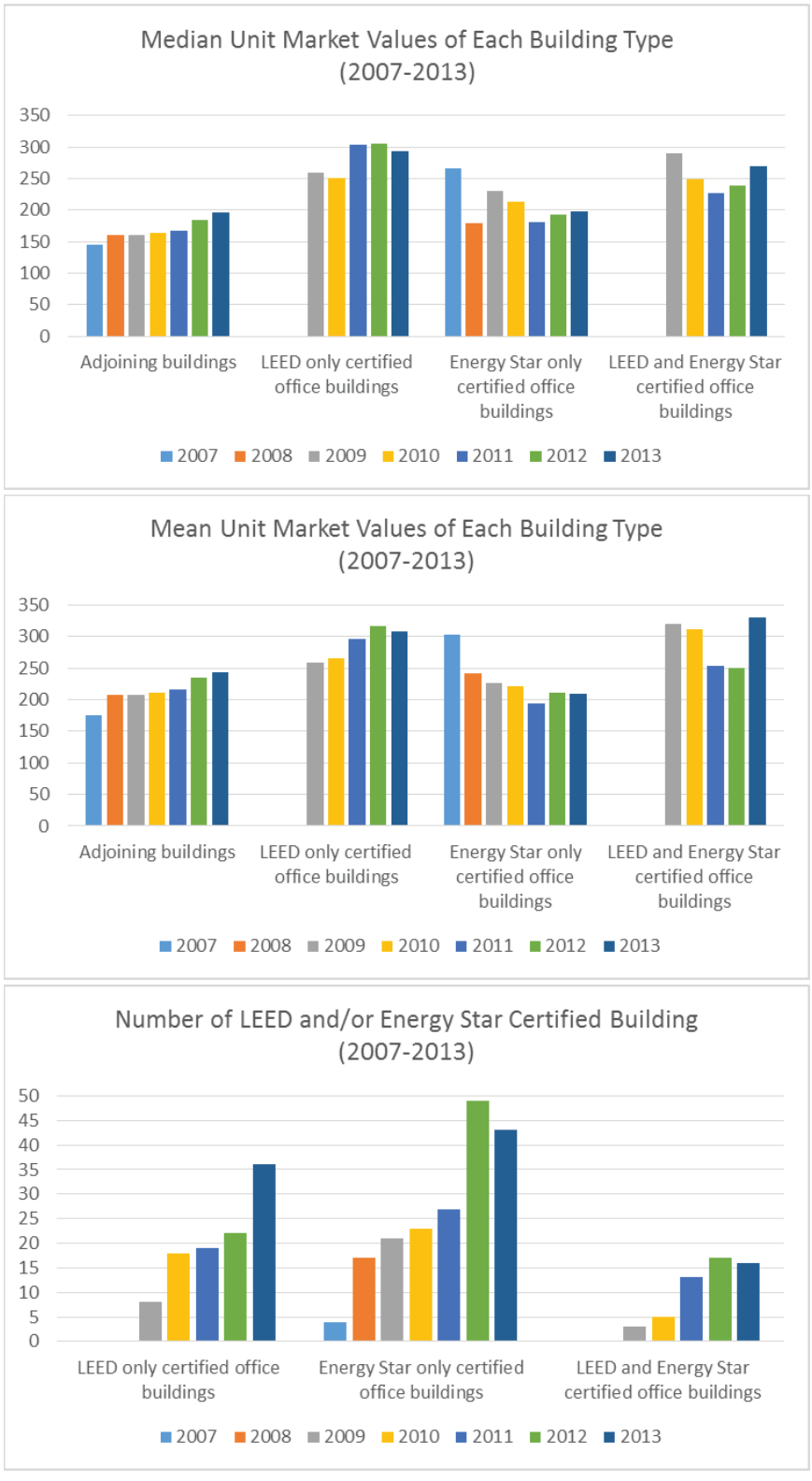


FIGURE 2. Overlapping buildings adjoining Energy Star certified office buildings.

number of LEED and/or Energy Star certified office buildings also increased steadily except for the year 2013, when the number of Energy Star only certified office buildings and the office buildings achieving both certifications decreased. The increase in the number of office buildings that achieved Energy Star only or both certifications, along with the median or the mean unit market value of those office buildings, indicate the change of unit market value within the similar range of unit market values of adjoining buildings. When Energy Star certification was first achieved for office buildings in Manhattan, the median or the mean of the market value of those buildings peaked at its highest value in spite of the limited number of Energy Star only or LEED and Energy Star certified office buildings in the research area. At the same time, the number of LEED and Energy Star certified office buildings followed a similar trend to that of the Energy Star only certified office buildings. In contrast, the median or mean unit market value of LEED only certified office buildings in 2009 did not reach its highest value; LEED only certified office buildings also followed similar trends for the median or mean unit market values of adjoining buildings during from 2009 through 2013. Energy Star certification requires the energy performance to be reevaluated annually in order to renew and maintain the certification for the following year, and this requirement meant that 62 percent of the Energy Star certified office buildings in this study did not continuously maintain their certifications after their first year of becoming an Energy Star certified office building, either due to a failure to reevaluate the building energy performance as required or a decision not to renew by the building stakeholders.

FIGURE 3. Buildings adjoining selected LEED and/or Energy Star certified office buildings in Manhattan, NYC.

FIGURE 4. Results of descriptive analysis (Median/Mean/Number).



Regression analysis

The correlations between the two unit market values for the certified office buildings and adjoining buildings over time exhibit a linear correlation, and the slope of the scatter plots in Figure 5 suggests a positive correlation between the two. The strength of the positive correlation can be clearly recognized in Figure 5, which shows the distribution of the data collected for this research. The subsequent regression analysis of this research consisted of an examination of the

FIGURE 5. Linear correlation between the unit market value of a LEED and/or Energy Star certified office building and those of buildings adjoining the certified building.

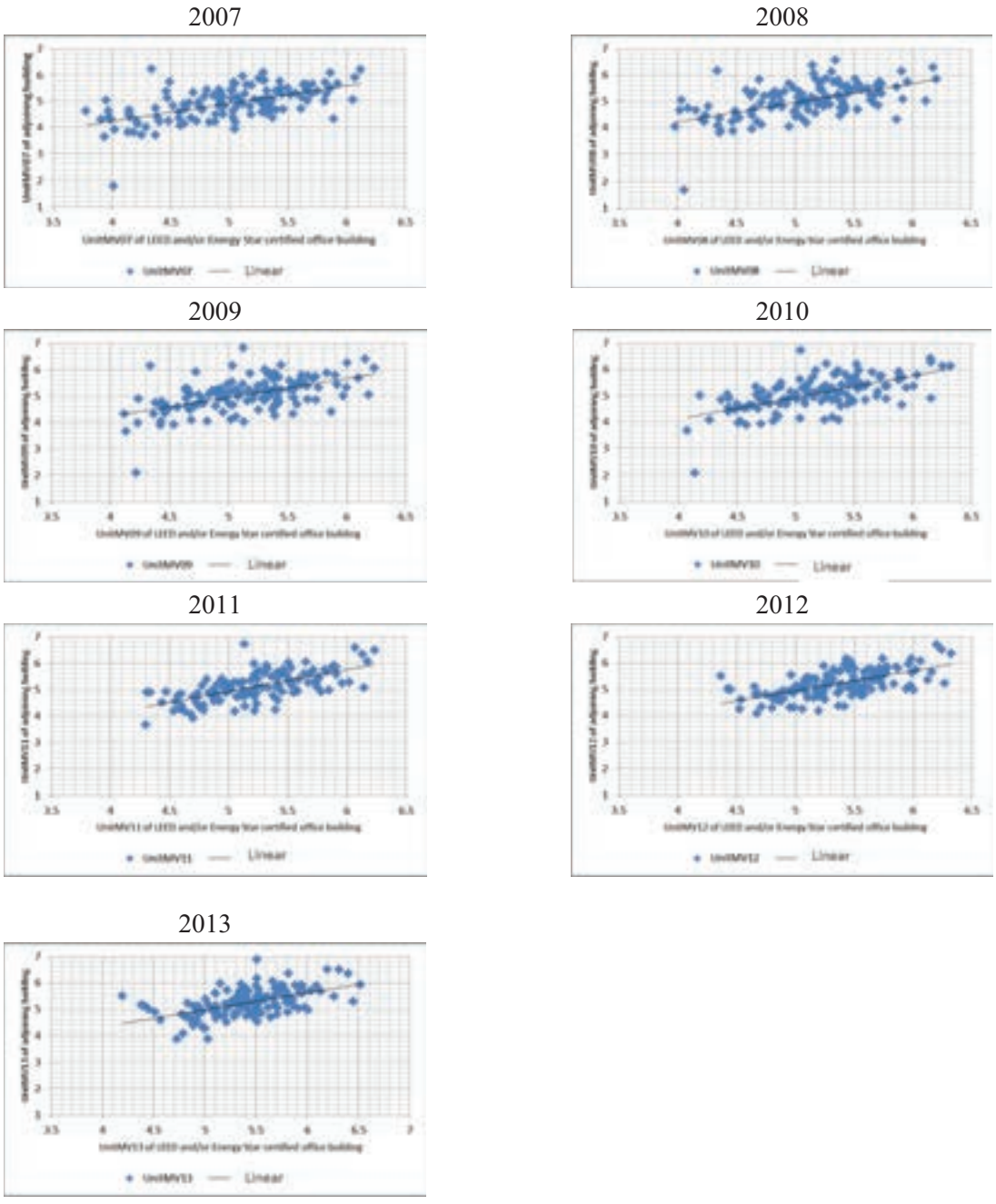


TABLE 4. R^2 values of hedonic price model equations for 2010.

	Linear	Log-linear	Semi-log	Log-log
R^2 value	0.2274	0.3066	0.2284	0.3177
Adjusted R^2 value	0.203	0.285	0.205	0.297

various linear correlation models. In order to select the most suitable linear equation model for this research based on the R^2 value, the hedonic price model was applied for each individual year from FY 2007 through FY 2013; the R^2 value for the log-log graphs consistently produced the highest R^2 value for each research year. The R^2 values in Table 4 are subjectively lower than other studies; however, Brown et al. (1999) suggested that the difference between high R^2 value and low R^2 value was caused by scale effects. The R^2 values for the four hedonic price model equations for 2010 are shown below in Table 4.

The values of the correlation coefficients between the unit market values of the adjoining buildings and those of each LEED and/or Energy Star certified office building also suggest that the log-log hedonic price model equation is the most appropriate for this research because the value of the correlation coefficient for the log-log equation, 0.51, is considerably higher than that of the next highest type, the linear equation, at 0.39. In addition, the hedonic model equation includes LEED or Energy Star certification as a variable because of the trend of the data. As a result, the regression analysis supports a data transformation on two unit market values for LEED and/or Energy Star certified office buildings and their adjoining buildings, hence the LMEM was run with the following equation.

log(Unit market value of adjoining bldg.) = log(Unit market value of LEED and/or Energy Star certified office bldg.) + LEED certification achievement + LEED certification level + LEED certification coverage + Energy Star certification achievement

Based on the above formula, the LMEM consisted of three top-down steps with which to evaluate the impact of LEED and/or Energy Star certified office buildings on the unit market value of adjoining buildings, taking into account two significant characteristics of LEED certification, as follows:

1) LMEM for the effect of achieving LEED and/or Energy Star certification

LMEM was applied to examine the effect of achieving LEED and/or Energy Star certification on the unit market value of adjoining buildings after the subject building has achieved certification by investigating the strength of the impact and its direction. The model equation takes the following form:

$$\log(\text{Unit market value of adjoining building}) = \beta_0{}^{7} + \beta_1 \log(\text{Unit market value of LEED and/or Energy Star certified office building}) + \beta_2 X_{\text{LEED certification}} + \beta_3 X_{\text{Energy Star certification}} + \alpha_0{}^{8} + \alpha_1 b^{9} + \varepsilon$$

7. The coefficients for fixed effects
8. The coefficients for random effects
9. The covariate for an individual building

Here, $X_{\text{LEED certification}}$ is the dependent variable (either 1, LEED certified, or 0, not LEED certified), $X_{\text{Energy Star certification}}$ is the dependent variable (either 1, Energy Star certified, or 0, not Energy Star certified), and b is the covariate for an individual building. The results indicate that all the independent variables are statistically significant in this model because the P-values for both LEED certification achievement and Energy Star certification achievement, 0.0023 and 0.0001, are lower than the significance level of 0.05 (Table 5). Moreover, the effect of LEED and/or Energy Star certified office buildings on the market values of adjoining buildings appear to have a positive impact on the unit market values, as these values play a role as the coefficient in the LMEM equation.

This indicates that for each dollar per sq-ft increase in the unit market value of a LEED and/or Energy Star certified office building, the unit market value of adjoining buildings also increased by about 49 percent based on the correlation (1.49212) between the unit market value of the adjoining building and the unit market value of its LEED and/or Energy Star certified neighbor, shown in Table 5. In addition, when an office building achieved Energy Star certification or LEED certification, the unit market value of an adjoining building increased by about six percent compared to its unit market value before its adjoining neighbor achieved the certification.

2) LMEM for the effect of LEED certification level

This LMEM examines the economic impact of LEED certification on the unit market value of adjoining buildings by analyzing the correlation between the four LEED certification levels and the unit market value of their adjoining buildings. For this analysis, the independent variables were the unit market values of the LEED certified office buildings and their LEED certification levels; the dependent variable was the unit market values of the adjoining buildings as per the following equation:

$$\log(\text{Unit market value of adjoining bldg.}) = \beta_0 + \beta_1 \log(\text{Unit market value of LEED certified office bldg.}) + \beta_2 \text{LEED certification level}_{(\text{certified, silver, gold or platinum})} + \alpha_0 + \alpha_1 b + \varepsilon$$

The result of LMEM for the effect of LEED certification level confirms that three of the four LEED certification levels, with the sole exception being Gold, were significant for the dependent variable due to the low p-value. Note, however, that although the p-value of the LEED Platinum level was significant, the screened population for the LEED Platinum level contained few members for the level of Platinum to be an effective statistical result. Table 6

TABLE 5. Result of LMEM for achieving LEED and/or Energy Star certification.

	Estimated coefficient	P-value	Impact
Intercept;(β_0)	3.0465895	< 0.0001	—
Log(Unit market value of LEED and/or Energy Star certified office building);(β_1)	0.4001741	< 0.0001	1.49212
Energy Star certification achievement;(β_2)	0.0595213	0.0001	1.06133
LEED certification achievement;(β_3)	0.0659072	0.0023	1.06812

TABLE 6. Result of LMEM for LEED certification levels.

	Estimated coefficient	P-value	Impact
Intercept;(β_0)	2.7393419	< 0.0001	—
Log(Unit market value of LEED and/or Energy Star certified office building);(β_1)	0.4623754	< 0.0001	1.58784
Certified;(β_2)	0.1197142	0.0026	1.12717
Silver;(β_2)	0.0986043	0.0036	1.10363
Gold;(β_2)	0.0054277	0.8690	1.00544
Platinum;(β_2)	−0.8668129	< 0.0001	0.42029

presents the p-values and the impact of each independent variable. This result indicates that two of the LEED certification levels, Certified and Silver, did indeed have a significant impact, exerting a positive effect on the unit market value of adjoining buildings. Moreover, it shows that the unit market values of adjoining buildings increased by about 10–12 percent once an office building achieved the Certified or Silver level of LEED certification.

3) LMEM for the effect of LEED certification coverage

This LMEM presented the effect of the extent of LEED certification coverage on the dependent variable; the model equation took the following form:

$$\log(\text{Unit market value of adjoining bldg.}) = \beta_0 + \beta_1 \log(\text{Unit market value of LEED certified office bldg.}) + \beta_2 \text{LEED certification coverage}_{(\text{Full or Partial})} + \alpha_0 + \alpha_1 b + \varepsilon$$

The result of LEED certification for only part of the building was not significant because the p-value was over the reference value, 0.05. In contrast to the above result, a building that achieved LEED certification for the whole building positively affected the unit market value of its adjoining buildings. Table 7 shows the results of the statistical analysis of LMEM for the effect of LEED certification coverage. It indicates that the effect of LEED certification coverage

TABLE 7. The impact of LEED certification coverage.

	Estimated coefficient	P-value	Impact
Intercept;(β_0)	2.8920720	< 0.0001	—
Log(Unit market value of LEED and/or Energy Star certified office building);(β_1)	0.4328395	< 0.0001	1.54163
Partial LEED certification coverage;(β_2)	−0.0516684	0.4870	0.94964
Full LEED certification coverage;(β_2)	0.0744265	0.0008	1.07727

on the unit market value of adjoining buildings was positive if the LEED certification extended to the whole building.

Model validation

The Log-likelihood Ratio Test (LRT) was utilized to validate the model by comparing the fitted model with the null model and the fitness of the model indicated through the numerical results, including the intercept and random effects for performing LRT. The null model indicated that the fitness of the fitted model would decrease if additional variables were added to the fitted model, which includes an intercept. The LRT hypotheses for the model validation applied were as follows:

H_0: The null model is true.
H_1: The null model is not true.

The results for all LMEMs revealed that the values of both AIC (the Akaike Information Criterion) and BIC (the Bayesian Information Criterion) for the fitted model were smaller than the equivalent values for the null model, so the LMEMs for the data from 2007 through 2013 in this study should be statistically better than the null model (Table 8).

CONCLUSIONS

The results revealed that there was indeed a correlation between LEED and/or Energy Star certification and the unit market value of adjoining buildings for the period from 2007 through 2013 from an economic standpoint. Moreover, the mere fact that a building had achieved LEED and/or Energy Star certification in most cases encouraged a positive change in the unit market values of adjoining buildings. LEED certification for the entire building and LEED Certified and Silver levels all had a positive impact on the unit market values of adjoining buildings. LEED certification for only part of a building and LEED Gold level were not significant as impact factors for adjoining buildings. The impact of achieving LEED Platinum certification on adjoining buildings was not studied due to their extremely small number in the data set during the study period. These findings indicate that in general both LEED and Energy Star certification have a positive impact on adjoining buildings. However, building stakeholders seeking to achieve the full benefits of LEED certification for their buildings should carefully consider the most appropriate LEED certification level and coverage needed to meet their goals. Their choices are likely to positively influence the sustainability of LEED or Energy Star certification due to the economic benefits that accrue to the buildings adjoining LEED and/or Energy Star certified office buildings as a social benefit.

TABLE 8. The results of the LRT.

	LMEM 1	LMEM 2	LMEM 3
LRT value	783.6022	261.5462	260.9993
P-value	< 0.0001	< 0.0001	< 0.0001
	Significant	Significant	Significant

Although this research focuses on a particular area, Manhattan NYC, and covers only a limited research period from 2007 through 2013, the findings provide a foundation for future research to investigate the impact of the various green building certifications and develop a prediction model for their economic impacts. This research also provides useful guidance for those seeking to achieve an element of the triple bottom line of sustainability for LEED and Energy Star certification from an economic standpoint by encouraging and supporting mutual growth in the local real estate market.

DISCUSSION AND FUTURE RESEARCH

At the time this research was conducted, the limited number of eligible buildings in the screened population adversely affected the quality and consistency of the available data. In particular, the shortage of buildings with the two higher LEED certifications, Gold and Platinum, meant that the statistical results for these two LEED certifications were not statistically significant. This is an important issue because a previous study (Dermisi 2009) concluded that the economic impact of LEED certification on the market values or the assessed values of LEED certified buildings can depend on the level and the type of LEED certification. Therefore, the screened population for Gold and Platinum levels of LEED certification needs to be increased to deliver meaningful statistical results in future studies. In addition, the buildings achieving multiple LEED certifications should be considered in more depth to determine the utility of multiple LEED certifications for buildings that have already achieved LEED certification and the impacts of multiple LEED certifications on the market values or assessed values of the LEED certified office buildings. The impact of losing Energy Star certification from Energy Star certified office buildings over time for adjoining buildings might be studied to identify any long-term economic consequences. Moreover, the particular area selected as the target research area here, Manhattan NYC, is subject to a number of limitations, and additional research areas should be added to overcome the tight geographical constraints of the present study. Moreover, future research is needed to consider the economic impacts of LEED or Energy Star certification at the neighborhood or community levels to determine the spillover effect, if any, of the certifications across a particular region economically and socially in order to encourage mutual growth among the stakeholders of LEED and/or Energy Star certified buildings and their neighbors and provide additional support for the sustainability of LEED or Energy Star certification.

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