ABSTRACT

Title of Dissertation:	IMPACT OF GREEN BUILDING CERTIFICATIONS ON THE ECONOMIC PERFORMANCE OF REAL ESTATE OFFICE ASSETS: NET OPERATING INCOME, AND MARKET VALUE
	Hossein Lavasani, Doctor of Philosophy, 2018
Dissertation directed by:	Professor Marie Howland, Department of Urban Studies and Planning

Following the existing line of inquiry on green buildings economic performance, this study hypothesizes that LEED and Energy Star green building certifications contribute to premiums in net operating income (NOI) and higher market value (MV) in commercial real estate office assets when compared to their broader conventional market competition. This study utilizes two of the most comprehensive proprietary databases in the U.S.: Real Capital Analytics (RCA) data on commercial asset sale prices and Trepp Inc. data on property income and expense information. Employing the hedonic regression analysis, and controlling for several building attributes including location, height, size, age, market perception of quality, transit score, walk score, etc., the study finds significant NOI and MV differentials across metropolitan statistical areas of five major U.S. gateway cities. The findings are encouraging and informative and may significantly contribute to the investment communities' understanding of how investing in green buildings can positively improve companies' economic bottom line.

IMPACT OF GREEN BUILDING CERTIFICATIONS ON THE ECONOMIC PERFORMANCE OF REAL ESTATE OFFICE ASSETS: NET OPERATING INCOME, AND MARKET VALUE

by

Hossein Lavasani

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Advisory Committee:

Professor Marie Howland, Chair
Professor Ralph Bennett, AIA
Professor Sonia Hirt, Ph.D.
Professor Margaret McFarland, J.D.
Professor Jelena Srebric, Ph.D.

I, Hossein Lavasani, acknowledge that the original work presented in this dissertation is my own intellectual property. I affirm that, throughout this dissertation, credit has been given to proprietors where information has been derived from other sources.

DEDICATION

To my mom and dad who gave me life, nurtured me and never stopped believing in what I can accomplish.

To my wife Saranaz, whose friendship, kindness, and compassion filled my heart with warmth … and to the memory of her mom whose strength, courage, and endurance inspires my every day.

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I have been very fortunate to be given the opportunity to tackle one of the most daunting projects one can ever accomplish; completion of a doctoral dissertation. As the saying goes, “the best dissertation is a DONE dissertation” and in so many ways the successful outcome of my PhD is surreal to me. Let’s face it, coming from an engineering background, with little knowledge in real estate development and urban economics, I had my fair share of fears and mixed emotions about the prospect of success in a new professional field. I am glad that I was able to muster a great deal of courage, determination, will power and perseverance to challenge, overcome and defeat procrastination, perfectionism and fear of failure. This would not have been possible without the support I received from my family. I would like to thank my parents and three siblings for their unwavering support and encouragement throughout the years. They taught me to be strong and determined, stay focused, disciplined and dedicated, work hard, keep my faith and never quit. I would also like to thank my lovely wife, Saranaz, and her dad for having faith in me and always being there for me through the ups and downs of the toughest yet most fruitful years of my life.

This dissertation is the reflection of my long and persisting fascination with real estate economics and how green buildings make a strong business case throughout my doctoral education. I would like to extend my greatest appreciation to my advisor Professor Marie Howland who always believed in me, supported my ideas and allowed me to have the freedom to pursue a research that was most interesting to me. I would also like to especially thank my supervisors Dr. Margaret McFarland and Dean Sonia Hirt for financially supporting my education, putting their trust in me to be their assistant and allowing me to contribute to so many successful academic and administrative projects. Their high standards helped me develop strong work ethics and encouraged me to continually raise the bar and push the envelope in growing intellectually, professionally and personally. I would also like to thank my other committee members, professors Ralph Bennett and Jelena Srebric, both of whom deserve special recognition. I would also like to thank other members of the MAPP family, staff and faculty alike. I consider myself very lucky to have the opportunity to study and work in such rarefied atmosphere. I have been blessed to be able to draw on the professional and academic support I received from outstanding advisors, mentors, and colleagues to achieve the burning desire of completing my PhD.

I am also in debt to my mentor Mr. Dan Winters of USGBC for his priceless time and invaluable guidance and support throughout this project especially in getting me authorizations to access Trepp and RCA proprietary archives of office assets' financial information. I am also happy and proud to acknowledge a great community of scholars; Scott Muldavin, Andrea Chegut, Frantz Fuerst, Gary Pivo, Avis Devine, Nils Kok, and Norm Miller for their expertise in green building economic performance and generosity in providing constructive intellectual and professional feedback on this dissertation. Their knowledge and insights have contributed to my research and development as an academic and continue to inspire me in my work.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

1.1 Sustainable Real Estate Development

1.1.1 Sustainability and the Built Environment

It is a well-documented fact that the built environment leaves considerable ecological footprint on the planet. During their construction, occupancy, renovation, repurposing, and demolition, buildings generate waste[1] and heavily consume energy[2], water, and raw materials (RICS, 2005; Berry, 2007; Krosinsky and Robins, 2008; Nelson et al., 2010). Accounting for 40 percent of raw material extraction, 40 percent energy consumption and 14 percent of potable water consumption, economic activity within buildings results in the single largest consumer of global energy and natural resources (Castro et al., 2009; Kibert, 2013). In addition to consuming considerable amounts of energy and natural resources, building-related emissions during construction and operation account for about 30 percent of global greenhouse gases (GHGs) emissions that markedly contribute to global warming and climate change. This is why an appreciation of the importance of making the built environment more sustainable has grown significantly over the past thirty years (Krosinsky and Robins, 2008).

The Brundtland Report (1987) defines sustainable as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The term 'sustainability' as applied to the building industry is a concept with three principle dimensions of environmental, social and economic often referred to as the

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[1] Building-related construction and demolition debris totals approximately 140 million tons per year, accounting for nearly 60 percent of total non-industrial waste generation in the U.S. (Choi, 2009).
[2] According to the U.S. Department of Energy, over the past decade buildings in the U.S. used more than 70 percent of all electricity generated much of which is utilized to operate commercial buildings (EIA, 2015).

“triple bottom line”[3]. To enhance the mission for sustainable development, the objective is to ensure that buildings are built and operated in a way that minimizes their environmental impact while maximizing social value, and economic output.

1.1.2 Green Building, Rating Systems and Certifications

Since the 1990s, there has been an ongoing global effort within the real estate industry to develop frameworks to influence building design, construction, and operation to deliver green buildings that are more resource/energy efficient and environmentally sound[4]. These efforts have prompted the creation of green building rating systems and certification programs such as Leadership in Environment and Energy Design (LEED) and Energy Star aimed at measuring a building’s sustainability and energy efficiency performance on the foundation of a defined set of sustainability-based criteria. Rating systems and certification programs are designed to recognize exemplary building attributes and/or performance and reward relative levels of compliance or performance with specific environmental goals and requirements in form of a green building certification. Green building rating systems and certification programs allow developers/investors to choose how to meet a certain sustainability benchmark and provide them with a metric to verify the relative sustainability of their projects/portfolios. They also provide building owners/operators with a solid post-construction and operation yardstick to assess energy efficiency and measure sustainability of properties they own and/or operate (Kibert, 2013).

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[3] The triple bottom line concept was coined by Elkington (1998) and incorporates a long-term view for assessing potential effects and best practices for environmental stewardship, social responsibility, and economic prosperity.

[4] Green buildings lower energy and water consumption, reduce natural resource depletion, and minimize GHG emissions (Miller et al., 2008; Turner and Frankel, 2008; Rohde and Lützkendorf, 2009).

While the definition of what constitutes a green building is constantly evolving, the most frequently used definition of green building can be summarized as follows: the practice of creating structures and operation processes that are environmentally responsible (planet), socially conscious (people) and economically sound (profit) throughout a building's life-cycle. In advancing the three pillars of sustainable development, the four principal objectives of green buildings are as follows: (1) lower inherent energy requirement; (2) conserve natural resource; (3) increase economic effectiveness; and (4) improve human health and well-being. To accomplish these goals, green building complements the classical building design concerns of utility, durability, and comfort through: (1) better siting; (2) better design, construction, renovation and demolition techniques; and (3) better operation and maintenance protocols.

1.1.3 Economic Objectives of Investment in Green Buildings

Over the past two decades a deeper understanding of the 'triple bottom line' value of green buildings has emerged, shifting the emphasis from 'planet' and 'people' to 'profit'. In today's competitive global market, many companies have come to understand how investment in green buildings can improve their financial bottom line while curbing the environmental footprint of their operations (Yudelson, 2016). This is an implicit indication that in evolved real estate markets the idea of environmental sustainability is intertwined with economic performance. Over time clear evidence continues to emerge demonstrating that green buildings offer a number of tangible and intangible economic benefits to owners, investors and space occupiers. In particular achieving LEED and/or Energy certification, whether through construction, rehab and/or acquisition, can deliver on economic priorities such as return on investment (ROI) and risk mitigation[5]. Within each company's portfolio, the presence or absence of green buildings can affect rental income and the future value of real estate assets, which in turn impacts the company's risk profile and their shareholders' risk-adjusted ROI. This explains why green building as an investment category has developed into a major component of the strategic asset allocation of institutional investors on a global scale (Kok et al., 2010; Sah et al., 2013; Eichholtz et al., 2015; Khan et al., 2015; Fuerst, 2015).

Within market-based economies, a building`s sustainability relies on an economic assessment method that motivates space suppliers to invest marginal capital in pursuing green certifications, and develop more green buildings. On the demand side, the end users which include tenants and buyers must see the economic merits and potential outcomes such that investment in green buildings justify market price differentials (i.e. rent and sale premiums) through reduction in total occupancy cost and/or increases in economic output. As a consequence, from an economic perspective, a company's main objectives in investing in certified buildings can be summarized as follows: (1) minimize the cost of operation and capital improvement expenditures (OpEx) throughout the whole life-cycle of a property; and (2) maximize the net operating income[6] (NOI), thereby creating market value[7] (MV) differentials.

When both scenarios hold true, a case for higher economic performance of green buildings can be made. As discussed below, investigating the impact of green certifications

[5] Superior economic performance in green buildings have been attributed to several tangible and intangible factors that are fully discussed in the following chapters.
[6] NOI equals all revenue from the property minus all reasonably necessary operating expenses.
[7] Market value is the estimated price at which a building will transact in the market place between a willing buyer and a willing seller.

on net operating income and market value differentials of real estate office assets lies at the core of this dissertation.

1.2 Defining the Study

1.2.1 Research Scope

Following the same economic rationale as mentioned above, while recognizing the critical importance of environmental and social components of sustainable development on underlying macro-economic fundamentals, this study consciously focuses solely on the increased economic performance of green office buildings certified under LEED and/or Energy Star certification programs[8]. This study bundles LEED and Energy Star certification programs and refer to them as 'green building certifications'. Therefore, the term 'certified' in this study is used to represent any level of LEED certification (Certified, Gold, Silver, and Platinum) and any top quartile Energy Star rating (75-100). In addition, this study categorizes all LEED certified and Energy Star labeled buildings into a single category by branding these buildings as 'green buildings'. As a result, the terms 'certified' and 'green' may be used interchangeably in this study. In contrast, the terms 'non-certified' and 'conventional' are used alternately in reference to buildings that lack green building certifications.

1.2.2 Research Motivation

The linkage between green building certifications and economic performance remains an area of significant academic and market-based research. In recent years, there has been a growing body of literature suggesting - through multiple lines of evidence - that

[8] LEED and Energy star certification programs are selected as a focal point of this study due to their prevalence in national scope and acceptance in the building industry. An overview of each program is available in Chapter 3.

commercial real estate assets with LEED and Energy Star certifications might in fact achieve superior economic performance including rents and sales price differentials that offer greater economic returns to developers, investors and building owners (Miller et al., 2008; Eichholtz et al., 2009a; Dermisi and McDonald, 2011; Fuerst and McAllister, 2009; Fuerst and McAllister 2011a, among others). There are some concerns, however, about the research's shortcomings in recent years.

In the presence of mounting academic and industry evidence on the financial implications of green certifications in commercial real estate, I have identified two major gaps within the existing literature as explained in the next section. To address the recognized issues in the current literature, this dissertation employs two fresh and rarely utilized databases to investigate the dynamics behind the economic performance of certified office properties across five major metropolitan areas in the U.S. Focusing on net operating income, market values, and capitalization rates this investigation is conducted within the context of supply and demand framework, measured *ex post* by sales transactions and achieved NOI over the periods of 2010-2015 and 2005-2015, respectively.

1.2.3 Research Objective

First, with a few exceptions (Pivo and Fisher, 2010; Devine and Kok, 2015)[9] the majority of research to date (see for instance, Miller et al., 2008; Eichholtz et al., 2009a, 2009b and 2010; Wiley et al., 2010; Fuerst and Mc Allister, 2009 and 2011b among others) has derived rental and sale samples through CoStar databases. Although claimed to be verified and accurate, CoStar data is not as complete and thorough as it is advertised. CoStar relies heavily on self-reported asking rents data which may be biased and/or

[9] Pivo and Fisher (2010) use NAREIT and Devine and Kok (2015) use Bentall Kennedy rental databases.

inconsistent with achieved rents and excludes incentives such as rent free period. This over-reliance on one database has restricted the literature's ability to confirm and validate results from CoStar database and benchmark those findings making reliable comparisons across other databases. In addition, these results are mostly based on cross-sectional studies of the U.S. market as a whole, where findings may be negatively affected by an omitted variable bias due to lack of focus on different metropolitan areas across the country.

Another issue could be discrepancies between databases and the inability to control for building characteristics that are correlated with green building certifications. As Eichholtz et al. (2009a) and Fuerst and Mc Allister (2011a) report, CoStar data has been prone to recording of erroneous data especially in data pertinent to sales transactions. For instance, they found a large number of sales prices that appeared too low to be regarded as regular free market transactions. Although, these scholars claim to have been able to identify the data errors and remove them from their sample, the potential implications of such data errors are not trivial. Given samples of thousands of transactions, investigating the reliability and source of each individual transaction can be extremely daunting and time consuming. Moreover, it can be argued that for the most part studies using CoStar database developed a methodology designed to provide broad general conclusions about the causality between LEED and Energy Star certifications and *ex ante* property price differentiation. Consequently, one may claim that the results might be applicable to strategic decision making, but are of limited use for tactical or property specific decisions. It is also worth noting that methodologically, the majority of these studies failed to address the issue of 'net investment benefits' or establish a link between net operating income, market value and capitalization rates in green buildings.

Secondly, with the exception of a handful research, the existing literature has focused more on the economic performance of office buildings providing evidence on rental rate, occupancy levels and sale price premiums. The existing literature provides limited insights into the implications of sustainability certifications on other crucial economic performance factors. More specifically, missing from this body of work is a thorough examination of the impact LEED and Energy certifications have on an important economic index that contributes most to the success or failure of investments in commercial real estate assets, namely net operating income. Moreover, to date there has been no analysis of the interaction[10] between net operating income, market values and capitalization rates with respect to economic performance of certified office buildings with leasing and sales data coming from two different sources. This dissertation makes two valuable contributions to the nascent literature through empirical investigation of this interaction as outlined in the following section.

1.2.4 Research Significance and Contributions

Although not unaddressed, the current literature on other asset classes is scarce. This is primarily because obtaining relevant data is difficult (e.g. location-specific business income data) and there is not as much depth in other asset classes. There are also asset-class-specific drivers' distinction that makes study on other commercial asset classes challenging (e.g. signaling and corporate image is not as important in industrial properties as they are in office/retail). Consequently, and in line with most of the current literature, this study only includes office buildings in analyzing the economic performance of

[10] The difference between gross potential income (GPI) and operating expenses (OpEx) lead to net operating income (NOI) of an individual asset which in turn determines market value (MV) of that asset by factoring in capitalization rate (cap rate) in any given market (MV=NOI/Cap Rate).

certified buildings. This study makes two major contributions to the current literature by providing a more accurate measure of the influence LEED and Energy Star certifications exerts on the economic performance of certified office buildings.

First, this study empirically investigates and measures price differentials, in terms of NOI and MV premiums, between LEED and Energy Star certified office buildings and their non-certified counterparts in the same submarket and within metropolitan areas of five major 'global gateway cities' in the United States[11]. While testing the validity of and confirming the findings of existing literature on sales premiums, this study reports the first findings on NOI of certified office assets that are tied to commercial mortgage backed security (CMBS) loans in five major U.S. metropolitan statistical areas (MSA). These large major MSAs include Boston, Chicago, New York, San Francisco, and Washington D.C. Comprehensive, accurate, and consistent data on rents, occupancy levels, net operating income, and operating expenses are available for all five MSAs[12]. More importantly, these markets are sufficiently different and diverse in their industry composition, climatic conditions, regulatory and policy framework, and their stock of office properties to allow for overall generalization of the results for major metropolitan statistical areas in the U.S. It should be noted that, these cities are leaders in adapting sustainability practice as it relates to the built environment. As of December 2017, the five MSAs targeted and selected for

[11] Global gateway cities are world class transport hubs networked into the global economy via their ports and airports. They are large important markets that have highly diversified economies with many sectors and subsectors that make them highly resilient to the ebb and flow of economic events. From a real estate perspective, global gateway cities are attractive to people and business meaning that space demand in their commercial real estate markets increases steadily over the long term, underpinning rent growth. They are also highly liquid markets, where real estate assets can be readily bought and sold.

[12] The investment community in five global gateway cities benefits from competitive markets for real estate advisory services at a very low cost. High market transparency and readily available financial information makes it feasible for seasonal investors/developers to successfully do trade frequently. For long term investors, real estate in five gateway cities provides good capital protection and in this era of low bond rates a good income return.

this research have all passed and enacted energy use benchmarking and disclosure ordinances as well as green building mandates. Although, the discussion on individual policy components of benchmarking laws and green building mandates and the likelihood of their success are beyond the scope of this dissertation, a brief synopsis of these policies can be seen in Appendix A.

Secondly, one of the novel features of this study is my ability to access, examine and analyze two different databases of commercial office buildings and to do so with unpreceded level of detail on their economic performance. These two databases are drawn from Trepp and Real Capital Analytics archives and are fully described in Chapter 3. Indeed, one of the most important strengths of this research is using truly 'comparable properties' in each submarket and across each MSA using these two proprietary databases. Every attempt has been made to improve the quality and uniqueness of this research, refine statistical hedonic models and increase reliability of findings. By developing a new methodological framework to investigate economic performance of green buildings, this study is the first to correspond findings on net operating income to the market value of office buildings in the same market controlling for building characteristics and certifications employing the income capitalization valuation method. I firmly believe that the inclusion of other determinants of economic performance (i.e. NOI, MV and cap rates) in this research, sets this study apart from the existing body of work. The results of the analysis[13] provides important new insights into the implications of energy efficiency and sustainability certifications and expands our knowledge about a broader range of factors

[13] The specifics of this analysis is further outlined in Chapter 5.

that influence value differentials in commercial real estate office assets with respect to LEED and Energy Star building certifications.

1.2.5 Research Question and Conceptual Framework

Following the existing line of inquiry on green buildings economic performance, this study hypothesizes that green building certifications contribute to higher rents, higher occupancy rates, and/or lower operating expenses which may individually or collectively translate into higher NOI, and MV differentials for certified commercial real estate office assets when compared to their broader conventional market competition. To test the hypothesis, this study utilizes a hedonic regression analysis after hedonic pricing model (Rosen, 1974), as outlined in the Chapter 4, to estimate the degree of contribution of green building certifications to net operating income and market values premiums in commercial office buildings. In doing so, this study takes advantage of two of the most comprehensive proprietary data sources, as described full in Chapter 3, that contain the most complete set of details on office buildings' hedonic characteristics.

The specific research question of this dissertation is as follows:

"What are the economic implications of green building certifications – both LEED and Energy Star – as demonstrated through 'higher net operating income' and 'higher market value' of commercial real estate office assets using actual market data from Trepp and Real Capital Analytics?"

The conceptual framework for this study is demonstrated below.

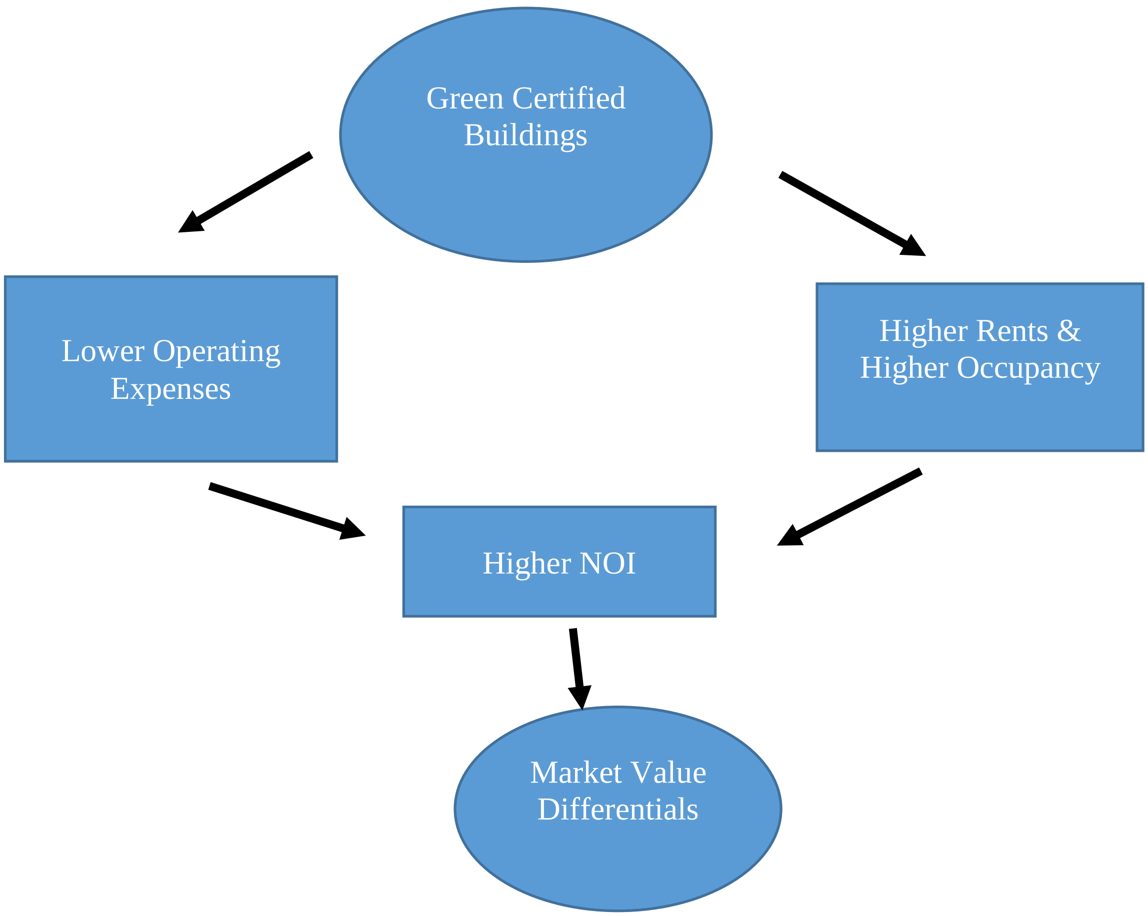

Figure 1: Dissertation Conceptual Framework

The ensuing chapters of this dissertation are organized as follows: Chapter 2, provides a thorough treatment on the existing body of research on economic performance of green buildings. It also lays the foundation for further understanding of green buildings' market dynamics and value. Chapter 3 presents data sources and provides description of data and data collection procedure. In Chapter 4, I discuss the methodology employed in this dissertation. In Chapter 5, I report the results of regression analysis and discuss research's findings. Finally, the dissertation concludes with a summary of research and findings, policy implications, and suggestions for future research direction.

CHAPTER 2. GREEN BUILDING ECONOMICS

2.1 Does Green Meet with Financial Success?

This chapter is dedicated to the review of literature on green building economics. So far as is concerned with green buildings, the primary question often asked within investment communities is typically, "Does investing in green buildings provide investors with economic returns sufficient to recoup the marginal investment (if any) required for sustainable features and/or green building certifications?" If we assume that financial motivation is the only driving force behind investment decisions, then it would be necessary to determine the value premium of achieving certifications. To better comprehend the underlying factors in green building investment decisions we need to learn more about cost and benefit tradeoff of pursuing green building certifications.

2.1.1 Green Building Cost-Benefit Analysis

Even though green building is gradually gaining market share, new construction and building refurbishment are still mostly conventional[14]. This raises questions about the marginal costs and benefits of certified buildings. The existing literature on cost-benefit analysis of green building revolves around two major arguments as follows:

1. Green buildings can be built at the same general cost (little or no added cost) as conventional buildings. In this case, showing that they have lower operating costs and/or produce other economic benefits provides sufficient evidence of their cost-benefit superiority. Without substantial added costs these potential added benefits serve to reinforce the economic motivation for investment in green buildings.

[14] Recent market data from CBRE shows that certified buildings represent 5.4 percent of the commercial office stock, and diffusion of such building practices is even more limited in other sectors, such as retail space and industrial warehouses (Holtermans et al., 2015).

2. Green building construction and delivery requires considerable marginal upfront investment. In this case, investment can only be justified if the cost premium incurred during construction and certification is balanced with cost savings through improved building operation (i.e. lower expenses) and higher economic returns (i.e. higher rents and/or occupancy rates, higher market value) over the asset's holding period or complete life-cycle as applicable.

With respect to these two major arguments, this study does not aim to investigate whether there is indeed an additional cost to comply with certification requirements; rather it sets to discover, regardless of the marginal cost, whether certifications can yield higher net operating income and market values in commercial real estate office assets.

2.1.1.1 Green Building Marginal Cost

A common presupposition among financial institutions and investors has been that sustainable buildings entail additional hefty cost, but do not always generate additional income (Matthiessen and Morris, 2004; Ries et al., 2006; Lockwood, 2008; Jackson, 2009). The perceived extra cost of building green followed by the longer duration of construction and delivery has been accounted by many scholars as the "number 1" investment impediment in pursuing certification both in new construction and/or existing buildings retrofits (Furr, 2009; Kiernan, 2009; Gibbons, 2010; Ashuri et al., 2010).

It is commonly believed that aside from the direct cost associated with using design and state of the art energy efficient technologies in certified buildings, there are also significant indirect costs of pursuing certifications. Typically these costs include fees paid to the certifying organization and green building consultant, cost of design review, construction review, implementation of some of the prerequisites and optional credits, along with the time spent to document credits. Given that green building is relatively novel in the construction industry, developers are understandably uncertain about their marginal cost relative to traditional property development. Design and certification fees are largely paid before construction is started, and are mostly paid from the developer's equity. These fees can thus be regarded as the premium that a developer has to pay for the option to develop a building. Moreover, the longer project lengths and higher variation in development duration for more efficient green buildings increase the uncertainty of total project costs and in turn of the developer's expected return on equity (Vink, 2009; Gibbons, 2010; Galuppo and Tu, 2010; Chegut et al., 2015). These impediments are likely to reduce the willingness of property developers to engage in green building practices.

Existing research on input costs is limited to a handful of outdated case studies, typically comparing a small number of green buildings to conventional counterparts, without properly controlling for other building characteristics and features of the construction process. As a consequence, the findings are hard to interpret or generalize. Anecdotal research shows that green buildings can be built and operated at reasonably small or no additional cost compared to conventional buildings[15]. Most notably, Matthiessen and Morris (2007) and Katz et al. (2010) document that, depending on the type and level of certification pursued, on average the additional upfront costs of green buildings are within 2 to 4 percent of the costs of design and construction of conventional buildings. Currently, there is no systematic empirical evidence addressing differences in input costs between green and conventional construction in the U.S. which hampers the understanding of policy makers, developers and real estate investors regarding the marginal costs of green

[15] See World Green Building Council (2013) and National Research Council (2013).

construction[16]. This in turn may slow down the diffusion of green buildings in commercial real estate market.

More recently there has been an overall trend towards the reduction in design and construction costs associated with green buildings. It could be argued that as building codes around the world become stricter, supply chains for green materials and technologies mature and the industry becomes more skilled at delivering green buildings, more competition and better expertise has brought the total cost of green building delivery to a minimum. It is also worth noting that while design and construction costs typically range from 5 to 10 percent, operation and maintenance costs account for 60 to 80 percent of total costs incurred over a building's life-cycle. Thus, the premium to design and construct green buildings (even if incurred) is relatively small when considered as part of the total life-cycle costs (Furr, 2009; Katz et al., 2010; Chegut et al., 2015).

2.1.1.2 Green Building Financial Benefit

Marginal investment in green buildings is almost always made in pursuit of attainment of superior economic outcomes. To compensate for the perceived additional costs of construction of certified buildings, rational investors will require a combination of higher income and/or reduced risk. The investment community, however, appears to be concerned about the possibility that any upfront marginal cost of certification fails to result in value differentials. The literature suggests that this concern is caused by two main misperceptions: (1) investors are ambivalent about broad-based claims regarding tenants' /buyers' willingness to pay a rent/sale premium for the package of benefits associated with

[16] Chegut et al. (2015) study the U.K. green building market and find that the average marginal cost of green construction is zero. However, the study reports that design and certification fees, representing just a fraction of development costs but paid largely upfront, are significantly higher for green buildings.

green buildings[17]; (2) investors are unsure whether green buildings actually operate on lower energy bills and incur lower total OpEx.

It can be argued that failure to observe the true value differentials in certified buildings would provide an economic disincentive to real estate investors that drastically hinders the supply of certified buildings given the perceived additional costs of certification. Consequently, an understanding of how certifications positively affect the income and value of commercial real estate assets is an important first step in making a business case for green buildings. That being said, there is now an abundance of reliable evidence that attest to the superior economic performance of green buildings which refutes misperceptions about green building financial rewards. Empirical studies find that, over the life-cycle of a building, in some cases financial benefits of certification amount to more than ten times the average upfront marginal investment required to design and construct a certified building (Pivo and McNamara, 2005; Wolff, 2006; Katz et al., 2010). From reviewing the literature it can be learned that financial benefits of green building certification can be attributed to a number of tangible and intangible determinants as discussed in the following sections.

2.2 Making the Business Case for Green Building

As explained in the previous section, the central concern for many investors is that do certified buildings cost more, command more rent, operate on lower expenses, and most importantly bring in higher asset value in term of a sale premium. For real estate investors/developers to pay the upfront additional cost of certification, they need to be

[17] This misperception is further exacerbated by the commonly held belief that lenders and the appraisal community do not fully recognize the added value of certified buildings during asset underwriting (Galuppo and Tu, 2010; Mapp et al., 2011; Fuerst and McAllister, 2011b).

confident that there will be a strong market for their products that offers higher economic returns on their marginal investment (Goering, 2009; Eichholtz et al., 2012; Kok et al., 2012; Reichardt, 2014). This section provides an overview of the literature and make a business case for higher economic performance of green buildings. In addition to direct and tangible financial benefits arising from better market appeal, academic research has also uncovered the implications of green building certifications on a number of intangible benefits[18] that can provide important competitive advantages to companies and ultimately translate into market differentiation and economic boost. A detailed review of the literature on the tangible and intangible implications of certifications on the economic performance of green buildings follows.

2.2.1 Tangible Economic Benefits and Value Determinants of Green Building

The most common tangible factors that play a role in added green value as found in existing academic literature fall into two distinct categories: (1) operating expense cost savings through water and energy consumption reductions; (2) income gains through higher rents and/or higher occupancy rates and sale premiums (RICS, 2005; Miller et al., 2008, Dermisi, 2009; Eichholtz et al., 2009a, Kapelina, 2010; Miller et al., 2010 among others).

2.2.1.1 Higher Energy Efficiency and Lower Operating Cost

Construction costs constitute only a fraction of a building`s total costs over its complete life-cycle (20 percent for a typical office building). The largest portion of building costs are incurred during the operation phase. These ongoing operational costs far

[18] Most of these intangible advantages are hard to measure and it is difficult to determine their pricing effects. Nonetheless, they have shown to positively impact the overall economic performance of green buildings.

exceed the construction costs of the building (Ebert et al., 2011). Representing more than 30 percent of the total operating expenses in a typical commercial building, energy is the single largest and most manageable operation cost in commercial real estate and can be measured with relative ease (Kiernan, 2009; kok et al., 2012; Reichardt, 2014). Consequently, energy efficient features offer real, quantifiable cost savings opportunities allowing companies to minimize operation and maintenance costs over the building life-cycle thereby increasing economic performance (Ciochetti and McGowan, 2010; Kapelina, 2010; Muldavin, 2010). Indeed, empirical research find that overall life-cycle energy cost savings in certified buildings exceed the average cost associated with pursuing certification (Pivo and McNamara, 2005; Wolff, 2006; Roper and Beard, 2006; Ciochetti and McGowan, 2010; Katz et al., 2010). Other researchers find that increased energy efficiency positively impacts the return on investment and is fully capitalized into rent and asset value premiums (Goering 2009; Eichholtz et al., 2010 and 2012; Kok et al., 2010; Reichardt, 2014).

Energy Star buildings are by definition more energy efficient than average buildings. Hence, studies find lower energy costs for these buildings. Katz et al. (2010) find that Energy Star labeled buildings use 40 percent less energy than an analogous subset from the national building stock, which result in lower energy costs of $0.50 per square foot. In a similar vein, Miller et al. (2010) find that electricity expenses in Energy Star buildings are lower by $0.35 per square foot. Pivo and Fisher (2010) find that utility expenses in Energy Star buildings are 12.9 percent lower per square foot per year. The studies on energy use in LEED certified buildings are inconclusive. Some studies show that LEED certified buildings use considerably less energy than conventional buildings

(Turner and Frankel 2008). Other studies, however, find that the energy use of LEED certified buildings varies considerably or that these buildings do not necessarily save energy (Newsham et al., 2009; Scofield 2009). For instance, Newsham et al. (2009) find that LEED certified buildings, on average, use 18 to 39 percent less energy. However, 28 to 35 percent of the LEED certified buildings in the sample use more energy as comparable conventional buildings. A possible explanation for this large variation is that LEED certification is a broader measure of the sustainability of the building. In LEED version 4 for New Construction and Major Renovation only 33 out of 110 possible points are related to the category energy and atmosphere. Thus, LEED certified buildings are not necessarily more energy efficient as the points for the certification may have been achieved in categories other than energy and atmosphere.

As can be understood from this discussion, cost savings from efficiency gains are at the core of the green building business case. However, it is worth noting that while there is broad evidence that green buildings are more energy efficient, there is no conclusive evidence that lower energy costs are necessarily equivalent to lower total operating expense in green buildings. In fact OpEx might even be higher in green buildings (Miller et al., 2010; Pivo and Fisher, 2010; Reichardt, 2014; Szumilo and Fuerst, 2014). As a possible explanation, it could be argued that green buildings may incur additional non-energy related expenses, because these buildings are more intensively managed and may require a learning curve for building operators due to their often more sophisticated building system.

Although previous studies do not show a clear result regarding lower total OpEx in green buildings, the commercial real estate market is beginning to show signs that a building with energy performance lower than market standards will need to attract tenants/buyers through price reductions (i.e. discounted rent/value), or may remain vacant for above average durations; making these buildings susceptible to faster depreciation and lower market values. Consequently, many real estate investors attribute lower risk premium to green buildings and perceive energy efficiency as a vehicle to achieve steady rental growth, a notion that have implicit impact on the overall value of their portfolio of real property assets (Eichholtz et al., 2015; and Fuerst, 2015).

2.2.1.2 Higher Rents, Occupancy Rates, Asset Value

Over the past decade, as more owners and space occupiers became knowledgeable about the collective advantages associated with green buildings, the market demand for leasing certified buildings significantly increased (Nelson et al., 2010; Wiley et al., 2010; Fuerst and Mc Allister, 2011a). Furthermore, greater transparency and information access aided by technology advances allow green buildings to enjoy more marketability than in prior market cycles (Chegut et al., 2010). To date, sustainable real estate research has mainly focused on commercial buildings, specifically office space. This body of literature provides consistent evidence of rental and sale price premiums and superior occupancy rates associated with green commercial buildings (Fuerst and McAllister, 2009; Ciochetti and McGowan, 2010; Kok et al., 2010; Wiley et al., 2010; Kok and Jennen, 2012 among many others).

Nelson (2007) uses CoStar office building data to compare LEED rated and Energy Star buildings to a large sample of non-certified commercial properties. He identifies a variety of descriptive differences in the two subsamples (with green buildings more frequently being newer, owner or single tenant occupied, and concentrated geographically in certain markets), and controlling for such differences finds LEED buildings to have higher occupancy and rental rates. Miller et al. (2008) completes a similar analysis, finding statistically insignificant loadings on the LEED and Energy Star treatment variables when explaining rental rates, but that LEED and Energy Star certified buildings experience sales price premiums of 6 and 11 percent, respectively. Eichholtz et al. (2009a) also completes a similar analysis to examine actual and effective rental rates. The authors find 3.3 and 10 percent statistically significant rent and effective rent premiums for Energy Star buildings. Additionally, the authors find a 19 percent Energy Star sales price premium, but are unable to find statistically significant LEED-related rent and sales premiums. These authors also have a recent extension to this research, verifying that these premiums still exist, even years after the introduction of green space to the office market (Eichholtz et al. 2010). Pivo and Fisher (2010) use the NAREIT database and identify 5.2 percent higher rents for Energy Star rated buildings.

Reichardt et al. (2012) use a difference-in-difference and a fixed-effects modeling approach on a large panel of U.S. office buildings from 2000 to 2009 and find average rent premiums of 2.5 percent for Energy Star and 2.9 percent for LEED certification. In addition, the authors show that rent premiums for Energy Star increased along with the growing interest in sustainable buildings from 2006 to 2008, when the average rent premium reaches 7 percent. Lastly, Fuerst and McAllister (2011b) also completes an analysis of CoStar office buildings in the U.S., selecting their comparable properties based on submarket definitions. Controlling for quality and location-specific characteristics, they find evidence that investment in green building certifications yields desired economic outcome. Their hedonic regressions find 5 and 4 percent rental premiums for LEED and

Energy Star certified properties, and 25 and 26 percent sales price premiums for buildings with those certification programs, respectively.

Research on other commercial asset classes has been scarce mainly because the depth of data in non-office market is much shallower. However, some scholars reported similar results in multi-family and retail properties. Devine and Kok, (2015) uses private data on rents, occupancies, and operating expenses and conclude that certification offers tangible and intangible economic gains to property owners. Bond and Devine (2015) use hand-collected unit-level rental data on every LEED certified multi-family building in the U.S. and report an increase in rents after earning LEED certifications. Devine and Chang (2015) evaluate retail properties to understand financial benefits of certification for space users. Using retail bank branches as a proxy, they determine that LEED certified braches do much better in annual deposit growth compared to their conventional counterparts. The finding of this research verifies claims about long lasting financial benefits of LEED buildings over their life-cycle in years past initial certification. However, Energy Star certification found to offer no income increasing benefit to the space user.

With respect to evidence of higher rents and occupancy levels, it could be argued that, ceteris paribus, landlords who charge higher rents will experience higher vacancy rates and/or longer lease-up and absorption periods. Therefore, it can be deduced that higher rents and higher occupancy rates do not necessarily correlate; in fact, often times these two value indices demonstrate somewhat of an inverse relationship[19]. An example is a landlord who lowers their rental rates slightly below market specifically in an attempt to increase occupancy rates which could result in the same gross income. However, with rents

[19] This *a priori* inference is confirmed through empirical investigation with evidence provided in the findings of this dissertation.

being quoted higher than market average, higher occupancy rates could be explained by higher demand from tenants' preferred choice to occupy certified buildings resulting in income/value differentials. Therefore, it is reasonable to project that, if certified green buildings are a tenants' preferred choice, then conventional buildings will be less able to compete in the real estate market which leads to a 'brown discount' for buildings that are not certified. Based on this observation, contrary to the empirical evidence that certified buildings command higher rents, it might be the case that green buildings command market rate rents while non-certified office spaces must compete for tenants more vigorously through price discounts.

Regarding evidence of higher asset values, this logic is equally applicable for the claims of sales premiums, where buyers might be paying less for buildings that lack green certifications (Sayce et al., 2010). This is to say that the case for value premiums lies in the presumption that green buildings will retain buyers' attractiveness and therefore are less subject to obsolescence. From this observation, it could also be argued that owners of green buildings are more inclined toward the long-term cost savings and value appreciation as opposed to merchant builders who recycle capital more rapidly and are less concerned with long-term values. Consequently, the lower supply combined with higher market appeal of green buildings shift market demand upward resulting in a price premium.

It is also worth mentioning that according to the majority of the studies cited above lower OpEx and the resulting cost savings considered to be a major source of rent premium that certified buildings command. This is claimed to be especially the case for buildings with triple net leases, where tenants directly benefit from savings in operating costs. However, as discussed in previous section, empirical evidence suggests that certification could actually be associated with a higher than anticipated total OpEx, which is the opposite of its expected effect and puts the "cost saving positive impact on rents premium" argument into question (Miller et al., 2010; Reichardt, 2014; Szumilo and Fuerst, 2014). From this rebuttal, it can be argued that cost savings from energy efficiency can only explain part of the rent premium. Thus, earlier findings of rent premiums might be the effect of other intangible factors unrelated to a building's total operating expenses[20]. The intangible determinants of superior economic performance are discussed below.

2.2.2 Intangible Economic Benefits and Value Determinants of Green Building

Aside from direct economic benefits, certified buildings create a number of other important intangible, albeit strategic, benefits for investors, owners, and developers. According to the literature, there are likely to be three main intangible factors that influence economic performance of green buildings. These intangible benefits include higher productivity of the workforce, enhanced corporate public image, and overall lower risk of doing business which may individually or collectively lead to higher cash flows and higher realized asset values in certified commercial office buildings (Sayce et al., 2010; Birkenfeld et al., 2011; Devine and Kok, 2015).

2.2.2.1 Better Productivity

Loftness et al. (2006) maintain that employment costs constitute a high proportion of a company's overall operating costs. Thus, few investments generate greater returns than those designed to boost labor comfort, contentment, performance and productivity. A growing body of research is devoted to the impact of working in certified space on employee's health, well-being and productivity and consequent parallel economic gains

[20] Rent premiums could also be the result of broader market dynamics of supply and demand forces which is further discussed in the following sections.

for employers. Empirical evidence suggests that a modest investment in soft features, such as access to pleasant views, increased daylight, fresh air and personal environment controls, can boost employees' productivity and quickly translate into significant savings for an employer (Loftness et al., 2003; Frej and Browning, 2005; Abbaszadeh et al., 2006; Ries et al., 2006; Miller et al., 2009; Newsham et al., 2012; National Research Council, 2013; Devine and Kok, 2015, Altomonte et al., 2016).

In terms of productivity gains, Loftness et al. (2003) assert that in the service economy, productivity gains for healthier indoor spaces may be worth anywhere from 1 percent to 5 percent of employee costs, or about $3 to $30 per square foot of leasable or usable space. This estimate is based on average employee costs of $300 to $600 per square foot per year (based on $60,000 average annual salary and benefits and 100 to 200 square foot per person). This means that with energy costs typically less than $3 per square foot per year, productivity gains from green buildings could easily equal or exceed the entire energy cost of operating a building (Singh et al., 2010). Some scholars such as Katz et al. (2003) and Yudelson (2007) have considered the links between occupier health and workforce productivity and the increased value of buildings. However, these studies are still inconclusive and employee's productivity index has proved to be somewhat unquantifiable. Although, as more companies come to appreciate the value of productivity improvements, green buildings are likely to become a central decision factor with respect to work space selection (Miller et al., 2009; Singh et al., 2010; Sparkling, 2012).

2.2.2.2 Enhanced Public Image

Over the past decade, there has been an influx of information about the influence of corporations environmental, social and governance (ESG) policy and reporting and corporate social responsibility (CSR) practices on the overall economic performance of companies. ESG is a term used by investors to evaluate corporate behavior and to determine the future financial performance of companies. An analysis of CSR policies and ESG standards can provide insight into the long-term prospects of companies which allows mispricing opportunities to be identified. Investors can find new market opportunities with companies that place the management of ESG factors at the core of their business (Nguyen, 2014; Fuerst, 2015).

An important and increasingly popular way for companies to improve their CSR and ESG metrics and gain positive reputation is to house their operations and invest in green buildings. This is mainly because green buildings offer significant benefits to the environment, to the health and productivity of occupants, and to the financial bottom- line of owners and investors. LEED and/or Energy Star certifications, therefore, can send a strong signal to the market and communicate important evidence of a company's credibility and commitment to high standard environmental policies and sustainability initiatives. The signaling[21] effect of investment in green buildings can enhance a corporate's public image which could translate into market differentiation and economic boost through increasing and sustained capital flow from investors (Nelson, 2007; Pivo, 2008; Fulton et al., 2012; Eichholtz et al., 2015; Fuerst, 2015). Although hard to quantify, an enhanced sustainability reputation may also enable companies to attract and retain more talented, skilled and productive workforce which is a key value creation tool in any organization. As the cost of

[21] Originally proposed by Spence (1973), in economics contract theory, signaling work to facilitate the efficient exchange of goods and services. In case of green buildings, certification is a signal to the market that suppliers can use to reduce information asymmetries.

recruiting and training new employees increases each year, talent retention gives investment in green buildings yet another compelling reason.

2.2.2.3 Risk Mitigation

Investors are often concerned with long-term performance of real estate assets in the face of various market risks and increasing cost of capital. This concept is important to understand in relation to financial analysis of green buildings primarily because real estate investors have a fiduciary duty to their shareholders and other beneficiaries. To fulfil their responsibility they need to ensure that risk-adjusted profits, which flow because of income produced in rent and increasing capital values of real estate assets, are achieved over short and long-term time horizons. It has been claimed that an important aspect of long-term value creation in green building is considering factors that contribute to risk mitigation as it pertains to building ownership and operation (Kok et al., 2010; Sah et al., 2013). Green buildings offer lower risk premiums through mitigating the exposure to regulatory risks and maintaining tenant/buyer attractiveness due to their unique energy efficiency and marketing characteristics (Eichholtz et al., 2015; Khan et al., 2015).

On the one hand, regulatory risks such as mandatory disclosure of energy efficiency, and green building codes have become increasingly prevalent in recent years putting energy efficient and green buildings at a competitive advantage compared to conventional and inefficient buildings. A related risk is that the wealth of incentives that governments and utilities now offer for going green will be increasingly replaced by mandates and penalties for those that do not. The likelihood of a federal carbon tax or cap-and-trade program, and the near certainty of stricter energy standards in building codes, will only compound the problem for owners of less efficient and non-certified buildings.

On the other hand, tenants increasingly consider the total cost of occupancy, including utility charges, and landlords with inefficient buildings will have to absorb some of those expenses, by either capping utility charges or setting rents proportionately lower. In either case, operating income suffers. Scholars such as Dermisi and McDonald (2011), Kok et al. (2010), and Eichholtz et al. (2015) take the view that buildings which lack certification will begin to lag behind in terms of rental growth and value creation. This will ultimately increase risk of portfolio obsolescence leading to adverse yield movements, faster depreciation, and increased cost of holding real estate assets (Stefan and Paul, 2008; Nguyen, 2014). Ultimately it will be occupational demand in green buildings that leads to lower risk of investments and is differentiated by higher rents and market value.

2.3 Economic Drivers of Green Building Value

This section provides an analysis of the supply and demand dynamics in order to determine how value gets created in real estate market. Employing the fundamentals of real estate economics, it then identifies factors that drive green building value premiums.

2.3.1 Fundamentals of Real Estate Economics

According to DiPasquale and Wheaton (1992), the real estate market is comprised of two distinct segments that are closely inter-related. These include the market for real estate assets (asset market) and the market for real estate space (space market). In the following sections I explore the link between asset and space markets. I then use this context to describe the impact of supply and demand economic forces on green building value.

2.3.1.1 Real Estate Asset Market

Since real estate is a durable form of asset, its production and price are determined in the asset market where buildings are exchanged between investors. The value of real estate assets largely depends on how many investors wish to own particular type of real estate assets and how many of such assets are available[22]. The new supply of real estate assets depends on the price of those assets relative to the cost of replacing them which is driven by demand for ownership of space. With growing demand, prices rise above replacement cost causing new construction to take place. When demand is satisfied, supply subsides and prices begin to fall back toward the cost of replacement.

2.3.1.2 Real Estate Space Market

Based on the type and quality of available stock of buildings, the demand in the space market is driven by tenants' needs and largely depends on rent. The function of the real estate market is to determine a rent level at which the demand and supply for space reach an equilibrium. All else being equal, with a fixed supply of space, when demand increases, rents rise.

Rent levels determined in the space market immediately affect the demand for real estate assets. This is due to the fact that when acquiring an asset, real estate investors are actually purchasing a current or future income stream. With growing demand in the space market, construction increases in the asset market. However, with continued construction, and as the supply of assets grows beyond space market demand, rents decline in the space market driving down prices in the asset market.

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[22] From an economic standpoint, ceteris paribus, an increase in demand to own these assets will raise prices.

2.3.1.3 Asset Market and Space Market Interaction

Figure 2 illustrates the long-run equilibrium between the asset and space markets. In Figure 2, the two right-hand quadrants represent the space market, while the two left-hand quadrants represent the asset market. The demand for space in the short-run is drawn in the NE quadrant which has two axes: rent and the stock of space. The NW quadrant represents the valuation part of the asset market and has two axes: rent and the price. The ray emanating out of the origin represents the capitalization rate for real estate assets which is the ratio of income to value of assets[23]. The purpose of the NW quadrant is to take the rent level form NE quadrant, and determine a price for real estate assets, using a capitalization rate.

The SW quadrant is the portion of the asset market where the construction of new assets is determined. The ray emanating out of the origin represents the replacement cost of real estate. Given the price of real estate assets from the NW quadrant, a line down to the replacement cost curve and then over to the vertical axis determines the level of new construction where replacement costs equal asset prices. The SE quadrant, represents the annual flow of construction which is converted into a long-run stock of real estate space. The ray emanating out of the origin represents that level of the stock that requires an annual level of construction for replacement just equal to that value on the vertical axis.

According the Figure 2, if the demand in the space market shifts upward, the rent level (R*) is the first factor to react (in this case increase in space market). In turn, the value (P*) of the property reacts (in this case increase in asset market). This is because a higher rent level increases the value of a property since the future forecast of cash flow streams

[23] This is the current yield that investors demand in order to hold real estate assets.

looks brighter. These two reactions will happen in the short-run. If these changes stay the same for a longer period of time, the next step is that construction (C*) will start to pick up (when price grows in asset market). As long as the value or price of a property is higher than the construction cost, new construction is profitable and thus construction continues in the asset market. This new construction, when completed, increases the total stock (Q*) of the real estate market, which in turn affects the demand and rent levels in the space market.

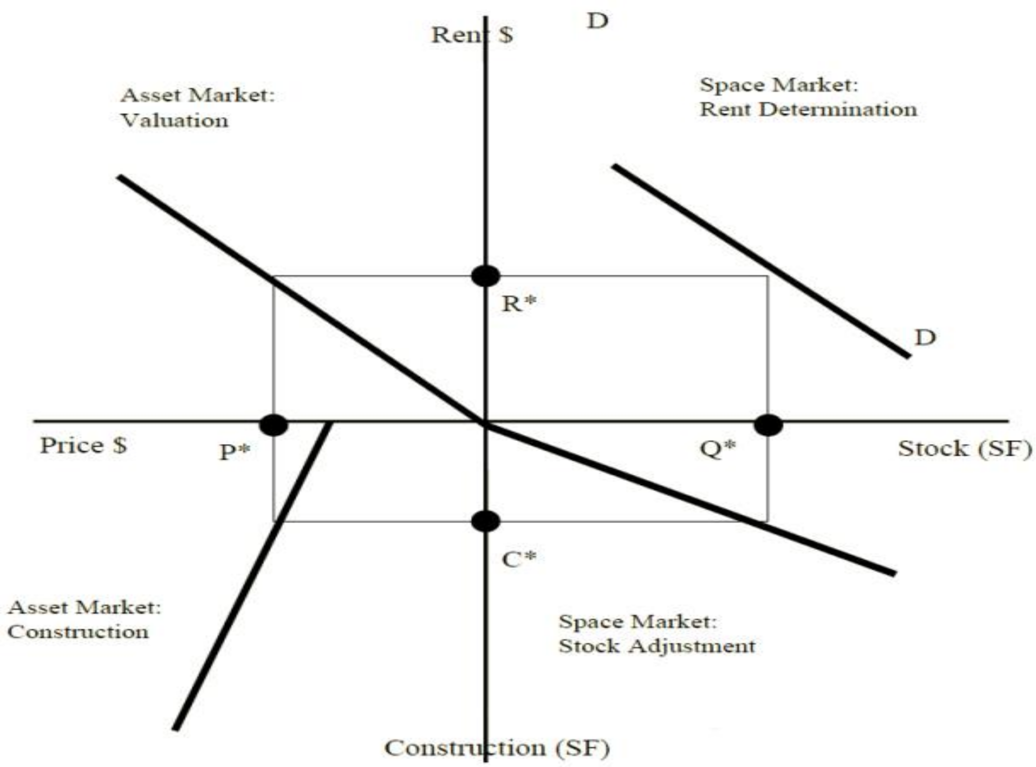

Figure 2: DiPasquale-Wheaton (1992) Space and Asset Markets 4-Quadrant Diagram

In summary, starting from stock of space, the space market determines rents which then get translated into prices by the asset market. These asset prices in turn generate new construction that back the space market, eventually yields a new level of stock. The combined space and asset markets are in equilibrium when the starting and ending levels of the stock are the same (i.e. supply satisfies demand). If the ending stock differs from the starting stock, then the values of the four variables in the diagram (rents, prices, construction and the stock) are not in complete equilibrium. If the starting value exceeds the finishing (i.e. shortage of supply), then rents, prices and construction must all rise to be in equilibrium. If the initial stock is less than the finishing stock (i.e. supply in excess), then rents, prices and construction must decrease to maintain equilibrium.

2.3.2 Supply and Demand Dynamics and Green Building Value

As shown by Sayce et al. (2010), the real estate sector and construction industry have been repeatedly criticized for being slow to respond to the increased focus on sustainability within a wider business context. Over the past two decades, a common experience has been the "circle of blame" impeding the market embrace and growth of certified buildings (Hopkins et al., 2011). This is best described as the suppliers of space - investors, owners, developers - claiming they cannot receive rent premiums as tenants don't demand it, while tenants claim there is shortage of certified space in market impeding choice, or otherwise they would demand it. However, in recent years significant momentum has been created that addresses both supply and demand factors leading to a market shift toward a more sustainable built environment (Chegut et al., 2013; Eichholtz et al., 2015)

On the demand side, improving a corporation's financial bottom line through tangible and intangible economic benefits of certifications is often reported as the primary driving force behind investment in green buildings. Consequently, space occupiers such as corporate tenants and federal agencies as well as institutional investors are showing tremendous interest in green buildings, thus increasing market demand for certified space.

On the supply side, price signals are central to the operation of real estate markets providing the information basis for the allocation of resources. For green buildings, prices need to reflect the costs-benefits analysis associated with ownership or lease of certified space. Higher risk-adjusted returns (i.e. income and value premiums) of certified assets potentially provide a signal that is transmitted from the space market to the asset market subsequently causing an increase in the supply of green buildings.

These economic forces of supply and demand are creating value and driving the green building movement forward; setting new standards in today's real estate competitive market. The following sections provide further discussion on the interaction of supply and demand forces and their impact on green buildings market value.

2.3.2.1 Drivers of Demand: Tenants Role and Impact on Value

According to Wheaton et al. (1997) the most important factor determining demand for rental space is employment in the legal and financial service sectors. Along these lines, Eichholtz et al. (2011) show that, with the economy recovering from the 2007-2008 financial crisis in the U.S., financial services firms, advertising and insurance sectors are dominant users of green space. Chegut et al. (2013) also provide evidence from the U.K. that supports this claim and attributes this new wave of tenants' inclination towards green buildings to superior economic performance, enhanced public image, and employee productivity. This indicates the powerful signaling effect of green building certifications in communicating a company's commitment to sustainability through housing its operations in a green building (Chegut et al., 2015; Devine and Kok, 2015; Fuerst, 2015).

The shift in tenants' preference in occupying green space suggests an increased level of market demand for certified assets thereby creating asset value premiums for owners/investors through an increase in risk-adjusted return on investment (i.e. higher rents and occupancy levels, lower operational cost and lower cap rates). This increase in demand is expected to continue to grow as the market penetration of green buildings expands[24].

2.3.2.2 Drivers of Supply: Investment Communities Role and Impact on Value

With the emergence of green building codes, policy incentives and benchmarking requirements to promote and encourage sustainable development, private investment in green building have grown steadily over the past decade and is projected to stay on the rise. The supply side is, therefore, encouraged both by the market demand shift toward green buildings and emerging incentives, codes, standards and regulations that call for building certified space. The increasing demand for certified space is usually well received by investments communities making them to look at financing green buildings construction and renovation projects more favorably (Eichholtz et al., 2015; Fuerst et al., 2016). This will in turn spur more development and result in an increased supply of certified space[25]. Given the short-run inelasticity of supply in the asset market, any increase in demand beyond the available stock of green buildings is likely to yield significant financial gains[26]. However, this equation is expected to flip once the supply reaches a critical mass. When

[24] Industry research supports this argument and shows that the growing demand is showing a tremendous positive impact on green building market expansion (Urban Land Institute, 2016).
[25] A recent study by Booz Allen Hamilton (2015) on economic impact of green buildings finds that despite the challenging economic outlook, green building construction industry supported nearly 8 million jobs in U.S. economy and contributed $554 billion to U.S. GDP between 2009 and 2013.
[26] By 2018, the same study finds, green construction will account for more than 3.3 million U.S. jobs, representing more than 30 percent of the entire U.S. construction sector, and generate $190.3 billion in labor earnings.

this happens, it is expected that green buildings become the norm rather than exception (Nelson, 2007; Chegut et al., 2011).

2.3.3 Income Capitalization and Green Building Value

One of the greatest challenges the investment community faces is an accurate assessment of the return on investment in green buildings and their value proposition. In the context of real estate, value is usually defined as the potential 'market value' of a property. According to the U.S. Appraisal Institute, there are three methods of determining the market value of a property as follows: (1) replacement cost approach; (2) sales comparison approach; (3) income capitalization approach. To determine the market value of income generating commercial property, investors primarily rely on the third approach. This is because income generating properties have a long series of cash inflows, in form of revenues, and a series of cash outflows, in form of initial acquisition/development, operating, maintenance and retrofit costs. The income capitalization approach[27] provides a logical investment framework based on a fundamental real estate market value determinant that is quantifiable, fairly measured and contribute most to market value, namely net operating income (NOI=Revenue-Operating Expenses). The market value can be defined as the ratio between NOI and cap rate and is expressed through the following equation:

Market Value=NOI/ Capitalization Rate[28]

[27] The income capitalization approach employs the discounted cash flow (DCF) analysis to calculate the net present value of future earnings derived from an investment in real property. An investment is considered lucrative when the value arrived at through DCF analysis is higher than the current cost of investment.

[28] Capitalization rate or simply 'cap rate' is the risk-adjusted return of an investment. Lower cap rates lead to higher building valuations, and as such are often associated with greater availability of capital and/or lower investment risk.

In looking at the market value equation, we can see simply that a building's value goes up as:

1. NOI increases (revenues go up and/or operating expenses decline); or

2. Capitalization rate decreases (reduced investment risk).

As mentioned earlier, with respect to investment in green buildings, investors need to make sure that a premium exists in market value that can offset the potential marginal cost of certification, design and construction of a green building[29]. To accurately assess the market value premium, the potential marginal cost should be weighed against the tangible and intangible economic benefits (i.e. a combination of higher income and lower risk) derived from green building certifications. Figure 3 below demonstrate income capitalization approach and value calculations in green buildings.

INCOME CAPITALIZATION OF GREEN BUILDINGS*

Gross Revenue	(higher rents)
-Vacancy	(lower vacancy vs. market)
=Effective Revenue	(revenue up)
-Operating Expenses	(lower utility bills, maintenance, reserves)
=Net Operating Income	(NOI up)
NOI/Cap Rate = Value	(lower cap rate)

Figure 3: Income Capitalization of Green Buildings (Ciora et al., 2016)

It can be seen from Figure 3 that in terms of gross revenues, higher rent represents a basis for future growth. Vacancy rate could end up in the effective revenues, as higher

[29] This is the basis on which investors/lenders assess the feasibility and risk level of a real estate project.

occupancy rate create more revenues. Aside from higher rents and occupancy levels, the most straight forward value proposition of owning a green building is lower operating expenses, realized through higher energy performance and green features, represented by lower utility bills, maintenance, reserves but also lower cost for facility management. The resulting cost savings are expected to reduce operating expenses and increase net operating income – which has a positive effect on value.

Figure 3 focuses only on tangible determinants of economic performance. However, to accurately measure the market value premiums in green buildings, intangible economic benefits of certifications should also be taken into account. Figure 4 complements Figure 3 and provides a much more sophisticated framework that explains the potential impact of green building certifications on NOI, cap rate and market value. This framework clearly reflects the business case for green buildings and is in tune with the tangible[30] and intangible[31] implications of certifications on the economic performance of green buildings discussed in previous sections. In this figure, five groups of determinants have impact on market value: market rent, owner expenses, risk premium, growth of owner income and depreciation of the property.

For example, the risk premium is reduced (-) by higher cash flows, improved marketability and shorter vacancy periods; the growth of incomes is increased (+) because the property is more competitive, will be less affected by the rise of energy costs than standard buildings, and will benefit the positive image linked to green buildings;

[30] Tangibles include: (1) lower operation costs through higher energy performance and energy savings; (2) higher income through higher rent/occupancy due to an increase in demand for green buildings.
[31] Intangibles include: (1) better productivity of the work force; (2) enhanced public image and corporate prestige through signaling; (3) risk mitigation and lower cost of capital through compliance with sustainability codes and standards and prevention of asset obsolescence.

depreciation of the building is reduced (-) because it has a longer life span and will comply longer with regulations, leading to lower costs for upgrades and building retrofits.

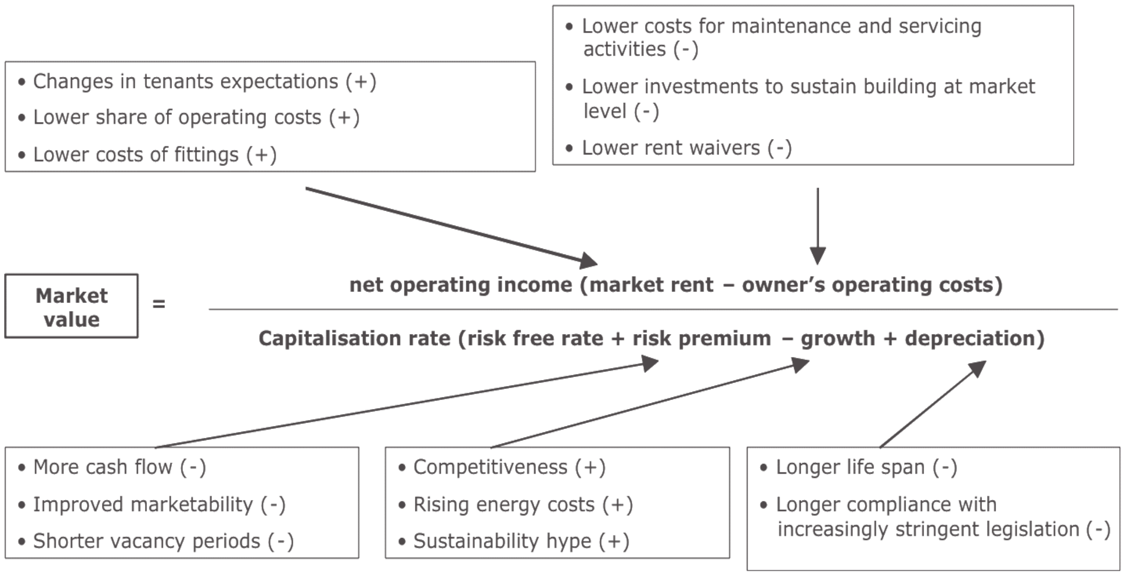

Figure 4: Market Value Equation and its Components in Certified Buildings (Lorenz, 2006)

Total investment return is composed of appreciation and income returns. Superior appreciation can occur if incomes grow faster than previously anticipated and/or if slower depreciation is expected in the future. Income return is the ratio of income to the property value at a given point in time[32]. If a certified building is expected to produce higher future incomes, it could produce higher appreciation and therefore be purchased at lower income returns (i.e. cap rate) in order to achieve the same total returns. This observation is in accord with the results of my quantitative analyses that green buildings with expected growth in income and value will tend to have lower cap rates. As is further discussed in Chapter 5, because cap rates are inversely related to risk, lower cap rates in green buildings indicate

[32] Income returns is an analogous term used for capitalization rate.

that, aside from generating higher income and market value, green buildings mitigate risk of ownership and could be viewed as safer vehicles of investment.

It should be noted that although income capitalization approach is a powerful method to assess market value of green buildings, as with any financial model, the quality of the output is contingent upon the quality of the inputs. If used without market-based support for the inputs or without proper benchmarking of the output, the result can be misleading. It is also worth noting that, with respect to the market value equation, one might assume that higher NOI and/or lower cap rates would, always and under any circumstance, logically lead to an increase in market value[33]. The nature of real estate is that every parcel of land is unique and heterogeneous, which makes it complicated to objectively and accurately compare buildings in the real estate market which is imperfect and characterized with information asymmetry. Even if having similar characteristics and are located in the same submarket, no two properties are 100 percent identical and therefore it is very difficult (if not impossible) to precisely isolate the effect of higher NOI or lower cap rates on market value. The real estate market forces of supply and demand act in a complex manner in different real estate cycles and consequently exert significance influence on real property market value.

[33] The income capitalization method can only predict the projected sale price at the end of the holding period for which an owner intends to keep a property. In reality, there are so many other factors and externalities that can affect market value.

CHAPTER 3. DATA

3.1 Data Sources

The most important issue in rigorous data analysis with respect to green building economics is identifying a reliable benchmark against which the sample of certified buildings can be compared. The ability to empirically and accurately test commercial buildings' economic performance is therefore highly dependent on the nature and validity of data sources. This is mainly because the commercial real estate market is highly fragmented and often not transparent; thus unverified market data is subject to information imperfections. To fix the effect of market imperfection on income and value analysis and to increase the accuracy and credibility of the statistical models, I utilize actual income and transactional prices data drawn from audited reports using Trepp and Real Capital Analytics (RCA)[34] archives. A brief description and relevance of each data source follows.

3.1.1 Trepp

The first set of data is drawn from the Trepp CMBS Loan database with detailed information on the economic performance of commercial real estate assets tied to commercial mortgage backed security loans. Trepp has a long-standing history in structured finance and is cited as the industry's largest commercially available database of securitized mortgages in the U.S. and is a market leader in its analysis of bonds and generated cash flows. The Trepp database consists of market performance information about more than 90,000 commercial real estate assets in the major metropolitan areas and their submarkets spread throughout the U.S. With a database supported by close to

[34] Access to both Trepp and RCA data sets has been obtained and authorized through USGBC for the purpose of this work.

$1 trillion in securities, Trepp provides unparalleled information, research, and surveillance on deals, loans, and properties with property income and expense data sourced directly from mortgage services[35]. This research utilizes the Trepp database for the purpose of analyzing net operating income with respect to green building certifications. Simply put, the economic information on certified and non-certified properties securitized by CMBS loans is used to determine whether building certifications are associated with income premiums.

3.1.2 Real Capital Analytics (RCA)

The second set of data is collected from RCA[36]. This database consists of information on more than 290,000 transactions of a wide array of commercial properties, certified and non-certified. Having recorded over $18 trillion of commercial property transactions, RCA is acknowledged as industry's largest database of commercial real estate transactions and property sales. It provides reliable real-time coverage of transaction data - across all markets and property types - with unique intelligence on market pricing, capital flows and real estate investment trends. This study relies on the RCA database for analyzing market value in relation to Energy Star and LEED certifications.

3.1.3 Green Building Information Gateway (GBIG)

Developed by the United States Green Building Council (USGBC), GBIG is the ultimate repository of green building information from around the world**.** This database refines competitive real estate markets by increasing transparency on key asset attributes

[35] 'Trepp Loan' offers a suite of web-based products for monitoring and analyzing securitized and non-securitized U.S. commercial mortgages and properties, whole loan portfolios and nationwide commercial mortgage financial statistics. Trepp Loan also delivers detailed information to give clients the insight they need for competitive advantage.

[36] RCA's data enables subscribers to view detailed information of a specific property or transaction, analyze it in context to the overall market and gain a big picture view by comparing trends within or across markets. This feature makes RCA's data the most trusted resource in the industry.

and reducing capital market information asymmetry. GBIG holds a wide array of detailed data on green buildings certified through two major energy efficiency and sustainability certification frameworks in the U.S., Energy Star and LEED. As of November 2017, GBIG shows more than 22,500 buildings certified under LEED and about 33,300 Energy Star labeled properties in the U.S. Evidently, a smaller portion of these properties fit in the commercial office real estate criteria used for the purpose of this analysis.

3.1.3.1 LEED

Developed by the USGBC in 2000 through a consensus based process, Leadership in Energy and Environmental Design (LEED), is a green building certification program that offers a suite of rating systems that is formulated to recognize projects that implement best practices strategies that increase profitability and performance, while reducing the negative environmental impacts of building and improving occupant health and well-being. Each rating system is comprised of requirements and guidelines that address the unique needs of project types on their path toward LEED certification. Each rating system[37] has four different level of certification, the number of points a project earns determines the level of LEED certification that the project will receive. According to LEED *V4*, up to 110 points are up for grab and may be earned across 9 basic areas that address key aspects of green buildings. The number of points available in each category varies slightly depending on which system is being used. These points correlate to a certification level. Higher levels of achievement are rewarded with higher levels of certification: Typical certification thresholds are as follow: Certified: 40-49 Points, Silver: 50-59 Points, Gold: 60-79 Points, Platinum: 80+ Points.

[37] This study does not address any specific rating systems within the LEED green building certification program.

Through independent verification, LEED provides building owners, design teams and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations, and maintenance solutions that positively contribute to the triple bottom line. LEED certification is a strong signal to all market participants that serve to represents high quality and standard in design, construction and/or operation of a certified building as compared to a non-certified building. LEED is driving international green building practices with more than 2 million square foot of construction space certifying every day. As of December 2017 and with over 100,000 projects currently certified and/or under consideration for certification across the globe LEED is the most widely used certification system in the U.S. and arguably the world and serves as a recognition standard for measuring building sustainability. Many U.S. federal agencies and states and local governments require or reward LEED certification. However, four states (Alabama, Georgia, Maine, and Mississippi) have effectively banned the use of LEED in new public buildings, preferring other industry standards that the USGBC considers too lax.

3.1.3.2 Energy Star

The Energy Star certification system is a program created jointly by the U.S. 'Environmental Protection Agency' and the 'US Department of Energy'. It began in 1992 as a voluntary labeling program designed to identify and promote energy-efficient products in order to reduce greenhouse gas emissions, and was extended to non-residential buildings in 1995. The Energy Star building certification system is used predominantly for existing building as an assessment tool to determine buildings' energy performance. Using a benchmarking method to assess a building's energy and water use, Energy Star program rates commercial buildings for energy efficiency.

The Energy Star certification is awarded based upon relative energy efficiency and environmental performance of a building. In particular, buildings can receive an Energy Star certification if the site energy use, the source energy use, and the greenhouse gas emissions of the building achieve certain specified benchmark levels. Energy Star certification is marketed as a commitment to conservation and environmental stewardship. It is also promoted as a vehicle for reducing building costs and for demonstrating superior management skill. Buildings that earn the Energy Star certification are the top performers for energy efficiency nationwide and use about 35 percent less energy than average buildings. These buildings typically include properly installed insulation, high performance windows, tight construction and ducts, energy efficient cooling and heating systems, and Energy Star qualified appliances, lighting, and water heaters. As of December 2017, more than 33, 000 buildings have achieved Energy Star certification for a total of over 4 billion square foot of certified space.

3.2 Data Description and Collection Procedure

First step in collecting data is to assemble and collate three large samples of commercial real estate assets in five MSAs from Trepp, RCA and GBIG databases. To identify the stock of certified commercial office buildings in Trepp and RCA, I utilize GBIG database on Energy Star and LEED building certification. Specifically, I use GBIG to determine the longitude and latitude geographical coordinates and street address of certified properties in five MSAs. I then match these addresses to the corresponding commercial office buildings identified in the archives maintained by Trepp and RCA (i.e.

original databases). After determining final matches in each database, I construct two separate datasets of certified properties using information from both data sources and complement these with manual collection of information on individual building's quality and characteristics. For each certified building, in each of the two samples of matched properties, I identify a control sample of nearby comparable non-certified office buildings based on their location, hedonic characteristics and other features. This results in a final sample of certified and comparable non-certified observations from each Trepp and RCA datasets as tabulated in the charts presented in sections that follow. I label these two datasets 'Trepp NOI' and 'RCA MV' samples, respectively. The objective is to carefully study and analyze observations from each sample to determine the impact of green certification on net operating income and market value of commercial office buildings.

3.2.1 Trepp Sample for Net Operating Income (Trepp NOI)

Across five real estate markets of Boston, Chicago, New York, San Francisco, and Washington D.C., the Trepp original database contains a total of 5,294 observations out of which 4,992 are non-certified properties. For the purpose of analyzing NOI, my GBIG match with this database yields 302 (i.e. 5,294-4,992) certified office buildings[38] in Trepp database, of which 124 were certified by LEED, 295 were certified by Energy Star and 117 were certified by both schemes[39].

Table 1 below, provides a brief summary of my match between certified office buildings, and the universe of all office buildings tied to commercial mortgage backed security loans identified in Trepp original database across five MSAs. Table 2 further

[38] Green represents buildings certified under either LEED or Energy Star programs.
[39] Dual represents buildings certified under both LEED and Energy Star programs.

provides a breakdown of the level of greenness[40] (i.e. type of certification category) of the matched 302 green buildings in each market and across Trepp original database.

Table1: Breakdown of Certified and Non-certified Office Buildings in Five MSAs (Trepp original database)

Market	**Certified (Green)**	**Non-certified (Conventional)**	**Full Sample**
Boston	24	271	295
Chicago	45	1,018	1,063
New York	112	2,753	2,865
San Francisco	51	384	435
Washington	70	566	636
Total	**302**	**4,992**	**5,294**

Table 2: Breakdown of Observations Based on Type of Certification Category in Five MSAs (Trepp original database)

Market	**Green**	**LEED**	**Energy Star**	**Dual**
Boston	24	10	24	10
Chicago	45	23	45	23
New York	112	36	112	36
San Francisco	51	15	51	15
Washington	70	40	63	33
Total	**302**	**124**	**295**	**117**

To investigate the effect of green building certifications on the net operating income of office buildings, the next step in collecting data is to assemble a sample of non-certified comparable properties to which the sample of certified properties in Trepp can be benchmarked. To do this, I correspond each of the certified buildings in the Trepp green sample (302 observations) to at least seven nearby non-certified comparable office buildings in the same submarket[41]. To identify the most comparable office buildings in the

[40] In both Trepp NOI and RCA MV samples, I define type of certification category as follows: (1) Green (either LEED or Energy Star certified); (2) LEED; (3) Energy Star; (4) Dual (Both LEED and Energy Star).
[41] I strive for seven comparable non-certified properties per each subject certified property, but elect to use fewer comparable properties rather than weaker comparables if presented with that situation.

non-certified sample in each submarket and within each MSA, I utilize a two stage procedure as follows:

First, I use Trepp 'underwriter property type' and 'subtype' features for commercial real estate assets to identify class A and class B office buildings. This study only focuses on class A and class B office buildings mainly due to the notion that market for higher class office space tends to be highly responsive to changes in sustainable design and construction technologies.

Second, I utilize the Trepp 'submarket identification' and 'delineation' features. Using these features, I identify all office buildings that are both characteristically and locationally most comparable to the subject certified property. Oftentimes, comparable properties are directly adjacent to the subject property, nearly guaranteeing locational equivalence. When this is not the case, the comparable property options are examined within the context of their geographical proximity. Based on the latitude and longitude of each certified building, I create 302 clusters of nearby commercial office buildings within a radius of 0.2 mile within the same submarket. Each small cluster - 0.12 square mile - contains one certified office building and at least seven non-certified comparables[42]. In total, there are 2,462 building in the constructed 'Trepp NOI' sample of which 302 are certified office buildings (treatment group) and 2,160 are non-certified comparable office buildings (control group)[43].

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[42] By treating each of the small geographic clusters as distinct, this analysis combines three common methods used in real estate asset pricing literature to analyze spatial variations: (1) including location dummies for submarkets (Glascock et al., 1990); (2) studying a specific MSA (Rosen, 1984); (3) specifying the distance of a property to specific locations (Sivitanidou, 1995).

[43] My approach to comparable property selection is in line with that of Bond and Devine (2016) in blending two methods separately used by Eichholtz et al. (2009a) and Fuerst and Mc Allister (2011b).

Current information about building characteristics and actual accounting data with great level of details for all of the 2,462 buildings in my 'Trepp NOI' sample are available. Several economic performance variables are closely analyzed. These include type of lease associated with each rental rate, occupancy rates, rents per square foot, net operating income per square foot, and total operating expenses per square foot. For the purpose of analyzing net operating income, I include all buildings in operation as of November 1, 2017, with data collected on or aggregated to quarterly basis for the 10 year period covering 2005-2015.

Table 3 below reports the number of certified and non-certified office buildings in each market as well as across the entire five MSAs Trepp NOI sample. It also gives an approximation for the fraction of observations (certified together with non-certified) in each market relative to all observations across the entire five MSAs full sample. As can be seen from the Table 3, New York and Washington D.C. contain some 60 percent of the observations across all MSAs which demonstrates the popularity of green buildings and prevalence of CMBS loans in these two important, globally recognized, and hot east coast real estate markets.

Table 3: Constructed Sample of Certified Office Buildings and Non-certified Comparables in Five MSAs (Trepp NOI sample)

Market	**Certified (Green)**	**Non-certified (Conventional)**	**Full Sample**	Percent
Boston	24	174	198	8%
Chicago	45	320	365	15%
New York	112	800	912	37%
San Francisco	51	366	417	17%
Washington	70	500	570	23%
Total	**302**	**2,160**	**2,462**	**100%**

3.2.2 RCA Sample for Market Value (RCA MV)

The second set of data used in this study includes a sample of sales transaction prices (i.e. market value), measured *ex post*, of class A and class B office buildings drawn from Real Capital Analytics database. Across five real estate markets of Boston, Chicago, New York, San Francisco, and Washington D.C., the RCA original database contains a total of 19,885 observations out of which 18,975 were non-certified properties. For the purpose of analyzing MV, my GBIG match with this database yields 910 (i.e. 19,885-18,975) certified office buildings or space (i.e. individual floor or unit) in RCA database that were sold between 2010 and 2015. Out of a total of 910 green office building/space, 390 were certified by LEED, 885 were certified by Energy Star and 365 were certified by both schemes[44].

Table 4 below, provides a brief summary of my match between certified office buildings that were sold between 2010 and 2015, and the universe of all office buildings identified in RCA database across all five MSAs. Table 5 further provides a breakdown of the type of certification category of the matched 910 green buildings in each market and across full RCA original database.

Table 4: Breakdown of Certified and Non-certified Office Buildings in Five MSAs (RCA original database)

Market	**Certified (Green)**	**Non-certified (Conventional)**	**Full Sample**
Boston	87	1,241	1,328
Chicago	171	3,523	3,694
New York	230	9,574	9,804
San Francisco	171	2,227	2,398
Washington	251	2,410	2,661
Total	**910**	**18,975**	**19,885**

[44] Same type of certification category is used for RCA MV sample, as defined in Trepp NOI sample: green, LEED, Energy Star, and dual.

Table 5: Breakdown of Observations Based on Type of Certification Category in Five MSAs (RCA original database)

Market	**Green**	**LEED**	**Energy Star**	**Dual**
Boston	87	36	87	36
Chicago	171	87	171	87
New York	230	74	230	74
San Francisco	171	50	171	50
Washington	251	143	226	118
Total	**910**	**390**	**885**	**365**

The next step in collecting data is to assemble a sample of non-certified comparable properties to which the sample of certified properties in RCA can be benchmarked. To do this, I assemble and analyze market data for the same five real estate markets with sales information available for Energy Star and LEED certified properties. The sample is restricted within these markets to include only observations with data on all of the building hedonic characteristics as specified in statistical models that ensue in the next chapter.

To investigate the effect of green building certifications on the market value of commercial office buildings, I correspond each of the certified buildings in the RCA green sample (910 observations) to at least seven nearby non-certified comparable office buildings in the same submarket. To identify the most comparable office buildings in the non-certified sample in each submarket and within each MSA, I utilize the RCA 'submarket' feature as well as property and space 'subtype' features. Based on the latitude and longitude of each certified building, and following the same comparable selection method and procedure described in previous section, I create 910 clusters of nearby commercial office buildings within a radius of 0.2 mile within the same submarket. Each small cluster - 0.12 square mile - contains one certified office building and at least seven non-certified comparables. In total, there are 7,420 building in the constructed 'RCA MV' sample of which 910 are certified office buildings (treatment group) and 6,510 are non-certified comparable office buildings (control group). Current information about building characteristics in addition to post-recession (between 2010 and 2015) market values for all of the 7,420 buildings in my 'RCA MV' sample are available.

Table 6 below reports the number of certified and non-certified office buildings in each market as well as across the entire five MSAs RCA MV sample. It also gives an approximation for the fraction of observations (together certified and non-certified) in each market relative to all observations across the entire five MSAs full sample. As the information suggests, together New York and Washington D.C. represent more than half of the observations across all MSAs. It can signals that these MSAs enjoy a hot real estate sales market and can be seen as a sign of market appeal and popularity of green buildings to large investors in these two large metropolis.

Table 6: Constructed Sample of Certified Office Buildings and Non-certified Comparables in Five MSAs (RCA MV sample)

Market	**Certified (Green)**	**Non-certified (Conventional)**	**Full Sample**	Percent
Boston	87	631	718	10%
Chicago	171	1,216	1,387	19%
New York	230	1,643	1,873	25%
San Francisco	171	1,227	1,398	19%
Washington	251	1,793	2,044	28%
Total	**910**	**6,510**	**7,420**	**100%**

CHAPTER 4. METHODOLOGY

4.1 Empirical Models

Chapter 4 outlines the methodology and econometric procedure employed in this dissertation. To investigate how green certifications influence the NOI and MV of commercial office buildings across five MSAs, I utilize hedonic regression modeling which is the standard valuation framework for commercial real estate assets (Rosen, 1974)[45]. In this method, the treatment sample of green office buildings and the control sample of conventional office buildings are used to estimate a semi-log equation relating net operating income and/or market value per square foot to the hedonic characteristics of a building (e.g, age, rentable building area, building qualities, number of stories, type of lease, amenities, walkability and proximity to public transportation, etc.).

For the purpose of this study, I specify two sets of hedonic models. Model (1) explains net operating income per square foot in achieved net income and Model (2) explains market value per square foot in realized sales transactions. The standard log-linear hedonic income and market value models take the following form:

$$\text{Model (1): Ln } NOI_{in} = \alpha + \beta_i X_i + \sum_{n=1}^{N}(\gamma_n C_n) + \delta g_i + \varepsilon_{in}$$

$$\text{Model (2): Ln } MV_{in} = \alpha + \beta_i X_i + \sum_{n=1}^{N}(\gamma_n C_n) + \delta g_i + \varepsilon_{in}$$

Where the dependent variables, NOI_{in} and MV_{in}, are the natural logarithm of average annual net operating income and market value per square foot, in commercial office building i in cluster n. X_i is a vector of hedonic characteristics[46] of building i; C_n is a dummy variable

[45] For MV this investigation is conducted through a transaction-based hedonic model measured *ex post* for sales that took place between 2010 and 2015.

[46] Several independent variables are included in the empirical analysis. The hedonic weight assigned to each variable is equivalent to the characteristic's overall contribution to the dependent variable (NOI and MV).

with a value of 1 if building *i* is located in cluster *n* and zero otherwise; and g_i is a dummy variable with a value of 1 if building *i* is certified through LEED and/or Energy Star (i.e. green) and zero otherwise; α, β_i, γ_n, and δ are estimated coefficients and ε_{in} is an error term that is expected to take the form of a normal distribution with a mean of zero. To control for market differences in demand for commercial office space, X_i also includes the percentage increase in employment in the service sector for the MSA containing a cluster of a green building and its nearby comparable controls. The increments to NOI and MV associated with a certified building is represented by exp [δ].

It should be noted that these models have not been constructed to predict sales prices or income growth in the future. To the contrary, they have been developed to measure the contribution of LEED and Energy Star certifications to net operating income and market values of commercial office buildings, independent of other variables. To do this, I use several control variables to isolate the effects of green building certifications on properties' economic performance. Most of the factors that influence NOI and property market values are included in these models. However, to limit the impact of potential omitted variables, a number of post-regression diagnostic tests (most notably an analysis of the residual errors) are conducted to check for systematic bias that might skew the results[47]. A thorough description of all variables included in hedonic models is provided in the next section.

[47] I use 'Stata' data analysis and statistical software package to estimate the regressions and report the findings. Stata's capabilities include data management, statistical analysis, graphics, and a variety of regressions.

4.2 Description of Variables

The value of a real estate asset can be examined by considering the set of property attributes. The objective here is to isolate the effect of certifications on a property's economic performance (NOI and MV) controlling for buildings' hedonic characteristics. My final constructed Trepp NOI and RCA MV samples contain physical characteristics (both functional and design attributes) and financial information on office properties across five MSAs. Physical characteristics variables include energy efficiency and sustainability certifications (LEED and/or Energy Star), total rentable building area (RBA), age, number of stories (height level), building class, building amenities, recent major renovations, distance to local transportation networks and walkability score (for MV)[48]. Financial information includes net operating income and/or market value, capitalization rates, occupancy levels (for NOI), and lease type (for NOI).

A full description of all dependent and independent variables used in two regression models is presented in Table 7 below. In addition to continuous variables such as cap rate, occupancy, RBA, age, and number of stories, I create and use indicator and categorical (dummy) variables to ease the statistical processing of models and increase accuracy of regression analysis. These indicator variables can be summarized as follows:

1. Market specific dummy variables are created to identify and control for regional market conditions in each real estate office market across five U.S. major MSA of Boston, Chicago, New York, San Francisco, and Washington D.C.

[48] These standard hedonic characteristics are expected to have a significant and positive impact on economic performance of green buildings, where larger, younger, taller, renovated and certified buildings located in prime CBD locations with amenities will have higher income and market values.

2. Beyond these market specific variables, separate dummies are created for submarket locational clusters to control for larger spatial effects that cannot be otherwise controlled. For the Trepp NOI sample in Model (1), there are dummy variables for 302 separate locations one for each of the 302 distinct 0.12 square mile clusters, which may affect office rents, occupancy rates and operation expenses which can individually or collectively influence NOI. For the RCA MV sample in Model (2), there are dummy variables for 910 separate locations one for each of the 910 distinct clusters that may affect a building's NOI and cap rates which can individually or collectively influence market value of commercial real estate office assets. This is particularly important because of the varying price levels across real estate market segments and geographical locations. It can also control for any state or local government incentives that might be granted to buildings that are certified.

3. Based on the type of certification category, certified properties are identified as 'LEED, Energy Star, Dual, and Green'. Dummy variables are used to distinguish different categories of certified properties[49]. This set up of dummy variables for specific type of certification prevents omission and/or dependency problems among these variables when there is more than one certification associated with a building. Although, outside of the scope of this study, this also makes it possible to separately measure the impact of each distinct certification type on economic performance determinants[50].

4. In both NOI and MV samples, age was selected as a control for contemporary design, operating expenses and functional obsolescence. Observations for building age are

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[49] This study does not control for specific LEED certification levels, LEED credits categories, and Energy Star scores.

[50] Where the combined effect of LEED and Energy Star certifications is greater than the sum of their individual effects, failure to include an interaction term (Green or Dual) produces a positive bias in the estimates of the individual label.

segmented into deciles to allow for potential time-varying age effect. To distinguish each age group, dummy variables are used.

5. Observations for building height are segmented into three categories of short, intermediate and tall. Dummy variables are used to distinguish different height levels.

6. Separate dummy variables are used to distinguish lease type (NNN or Gross) and building class (Class A and Class B).

7. Distance to transit[51], presence of building amenities and recent major renovations are also distinguished using dummy variables.

It is also worth mentioning that regional economic conditions were controlled with the annual regional employment growth rate as a measure of local demand. Office occupancy rates are used as a proxy to measure supply and demand balance. However, regional market conditions were not controlled with the yearly growth rate of office buildings in the region as a measure of local supply[52].

It should also be noted that two of the continuous numeric economic performance variables of NOI and MV are transformed to log NOI and log MV values to: (1) reduce skewness and non-normality found in initial examinations of the samples; (2) reduce heteroscedasticity; and (3) to be able to interpret the coefficients as elasticities. This transformation of indicative economic performance dependent variables in addition to the structure of dummy variables allow for capturing the most accurate impact of certification on office buildings' NOI and MV in each MSA and across full sample.

[51] Properties that were ½ mile or less (10 minutes walking distance) from a transit station were categorized as transit-oriented properties.

[52] This office market index was unavailable for this study.

Table 7: Description of Variables

Variable Definitions[53]		
Variable Name	**Variable Subcategory**	**Variable Description**
Market		Five major metropolitan MSA
	Boston Chicago New York San Francisco Washington DC	Dummy variable for Boston Metropolitan Area (1=yes) Dummy variable for Chicago Metropolitan Area (1=yes) Dummy variable for New York Metropolitan Area (1=yes) Dummy variable for San Francisco Metropolitan Area (1=yes) Dummy variable for Washington DC Metropolitan Area (1=yes)
Certification Category		Four distinct categories for type of certification
	LEED EnergyStar Dual Green	Dummy variable for LEED certified property (1=yes) Dummy variable for Energy Star labeled property (1=yes) Double Certification (LEED and Energy Star) (1=yes) Green Rating (LEED or Energy Star) (1=yes)
NOI Log NOI		Net operating income (PSF) per year Logarithm NOI (PSF)
Market Value Log Market Value		Market value (PSF) Logarithm Market value (PSF)
Cap Rate		Cap Rate: average income return of the property for the year
Occupancy		Percent property occupancy
Rentable Building Area*		Building Size (1000 of square foot)
Age*		
Age Groups		Subcategories for property age
	Age1to10 Age11to20 Age21to30 Age31to40 Age41to50 Age51up	Indicator variable for Age 1-10 (1=yes) Indicator variable for Age 11-20 (1=yes) Indicator variable for Age 21-30 (1=yes) Indicator variable for Age 31-40 (1=yes) Indicator variable for Age 41-50 (1=yes) Indicator variable for Age 51 & up (1=yes)
Stories*		Number of stories
Height Level		Sub categories for building height
	Short Intermediate Tall	Indicator variable for Height<10 (1=yes) Indicator variable for Height 10-20 (1=yes) Indicator variable for Height>20 (1=yes)

[53] Size, age, height and building class (variables denoted by an asterisk [*]) are used to control for building quality. They also serve as proxies to measure an asset's ability to generate higher income and market value.

Variable Definitions (Continued)		
Variable Name	**Variable Subcategory**	**Variable Description**
Building Class*		Building Class
	Class A Class B	Dummy variable for class A building (1=yes) Dummy variable for class B building (1=yes)
Lease Type[54]		Type of Lease
	NNN Gross	Dummy variable for net lease (1=yes) Dummy variable for gross lease (1=yes)
Transit Oriented[55]		Dummy variable for proximity to transit within 1/2 mile of rail transit station (1=yes)
Amenities		Dummy variable for offering amenities (1=yes)
Renovated		Dummy variable for major renovations (1=yes)
Walk Score		Property walkability score, scales from 0 to 100

[54] Lease types considered in the NOI models include 'Full Service Gross' (landlord pays all utilities) simply referred to as 'Gross' and Triple Net (tenant pays all utilities) simply referred to as 'NNN'.

[55] Data on the latitude and longitude of all U.S. fixed rail transit stations across five MSAs were obtained from the U.S. Bureau of Transportation Statistics (BTS), National Transportation Atlas Database and Google Earth. This included stations for commuter trains, heavy rail, light rail, and monorail.

CHAPTER 5. RESULTS & DISCUSSION

This chapter provides a systematic analysis of the impact of green building certifications on two of the most important economic performance outcomes as measured in the real estate market place. Concentrating on commercial real estate office assets, I investigate the relationship between investment in energy efficiency and sustainability in design and construction and pursuing green building certifications - as measured by Energy Star and LEED standards - and the net operating income and market value acquired by such properties.

5.1 Data Analysis: Descriptive Statistics

This section paints a clear picture of descriptive statistics for both NOI and MV evaluating each MSA and full Trepp NOI and RCA MV samples of 2,462 and 7,420 observations. It should be noted that these descriptive statistics do not distinguish for geographical differences across MSAs and submarkets, quality of office buildings and/or their lease types. Nevertheless, they can provide vital information on the overall market trends and economic output of office buildings in five major MSAs of the U.S. Regression analyses described in section 5.2 provides empirical evidence which sheds more light on observed signals and expectations drawn from descriptive statistics in this section.

5.1.1 Descriptive Statistics: Trepp NOI Sample

Table 8 provides summary statistics describing average values for rent, NOI, OpEx, occupancy, age, rentable building area, and building height[56] with respect to certified and non-certified office buildings for the full Trepp sample across five MSAs. From Table 8, it can be observed that on average green buildings are younger (thus they are less likely to

[56] Number of stories is used as a proxy for building height in this dissertation.

have undergone major renovations), slightly shorter, and offer substantially more rentable building area[57]. It is also clear from the table that on average certified office properties command higher rents but have slightly higher vacancy rates. Although their OpEx is higher, certified buildings generate more net operating income compared to non-certified comparable buildings in their control sample.

For the entire Trepp NOI sample of 2,462 office space across all five MSAs, the average NOI for certified office building is $31.43 and the average NOI for a non-certified office property is $24.35. From an economic performance standpoint, this higher NOI can be the result of higher rents, higher occupancy levels and/or lower operating expenses (individually or collectively). As the table suggests, some of this green premium can be attributed to higher rents ($55.13 for green and $43.99 for conventional). With occupancy rates slightly lower in green buildings (90.73 percent for green and 90.95 percent for conventional), one might naturally think that another portion of this higher NOI in certified buildings could be attributed to lower OpEx resulting from using more energy-efficient certified office space.

Interestingly, it seems that the total OpEx in green office buildings is in fact higher than their conventional peers, across all five markets ($21.39 for green, $16.43 for conventional). Similar results can be seen in each individual MSA market with New York showing the highest differentiation ($28.17 for green, $21.00 for conventional). Although appears to be odd, higher total OpEx in green buildings is in line with my expectations and consistent with other scholars' findings in recent years (Miller et al., 2010; Pivo and Fisher, 2010; Reichardt, 2014; Szumilo and Fuerst, 2014). As mentioned in Chapter 2, according

[57] Larger size of green buildings have been a central focus of previous research and is herein confirmed. The empirical evidence for the NOI and MV premium contributed by large RBA is provided in section 5.2.

to these findings, while there is broad evidence that sustainable buildings are more energy-efficient, there is no conclusive evidence that total operating expense are necessarily lower in sustainable buildings[58]. One common explanation for higher OpEx in green buildings is that larger office buildings with higher quality (i.e. Class A) require more costly and rigorous maintenance and management practices and may need a learning curve to efficiently operate their typically more sophisticated technical equipment. To further analyze the impact of OpEx on NOI and consequently MV separate hedonic models needs to be designed and regression analyses conducted. With that being said, this study focuses only on NOI and MV and the investigation of higher OpEx does not fall within the scope of my analysis.

[58] By definition green buildings (especially energy star labeled office buildings) are more energy-efficient and therefore their operation incurs lower energy cost. However, energy costs only represent 30 % of the total operating expenses (Wiley et al., 2010). In addition to energy costs, operating expenses include expenses for water, maintenance, cleaning, management, security, insurance and other operating expenses. Therefore, lower energy costs are not necessarily equivalent to lower total operating costs.

Table 8: Summary Statistics by Market by Green Designation - Trepp NOI Sample

Market	Rent ($/SF)			NOI ($/SF)			OpEx ($/SF)			Occupancy (%)[*]		
	Green	Conventional	Total	Green	Conventional	Total	Green	Conventional	Total	Green	Conventional	Total
Boston	51.79	33.04	35.31	28.49	20.82	21.75	13.1	9.58	10	91.49	93.7	93.44
Chicago	34.82	26.68	27.68	17.06	13.87	14.26	10.24	8.32	8.56	87.27	88.76	88.58
New York	64.53	52.55	54.02	38.07	28.38	29.57	28.17	21	21.88	92.61	90.6	90.85
San Francisco	53.88	42.75	44.11	28.56	25.65	26	14.56	13.08	13.26	91.92	93.2	93.05
Washington	55.23	46.09	47.21	33.14	24.89	25.9	25.51	19.16	19.94	88.81	90.31	90.13
Total	55.13	43.99	45.36	31.43	24.35	25.22	21.39	16.43	17.04	90.73	90.95	90.93

Market	Age (Yrs.)			RBA (1000 SF)[**]			Stories[***]			Observations		
	Green	Conventional	Total	Green	Conventional	Total	Green	Conventional	Total	Green	Conventional	Total
Boston	28.25	36.9	35.85	342.16	257.08	267.4	24.25	30.07	29.37	302	2,160	2,462
Chicago	80.07	92.1	90.61	64.56	83.22	80.92	27.13	34.67	33.74			
New York	47.54	61.24	59.56	848.48	522.77	562.77	31.07	29.93	30.07			
San Francisco	45.22	56.91	55.48	240.65	168.88	177.65	26.25	26.8	26.73			
Washington	30	39.92	38.7	317.29	184.37	200.69	11.21	10.94	10.98			
Total	46.39	58.18	56.74	465.66	297.95	318.52	24.53	25.72	25.57			

[*] New York is the only exception in terms of occupancy rates where conventional buildings show higher vacancy levels compare to green buildings.
[**] Chicago is the only exception where conventional buildings offer about 9,000 SF larger RBA on average compared to green buildings.
[***] New York and Washington DC are the only exceptions where green buildings are slightly taller on average relative to their conventional counterparts.

5.1.1.1 Lease Structure Analysis: Trepp NOI Sample

The total OpEx in green buildings compared to those of conventional buildings results in different NOI outcomes depending on the lease structure. An investigation of the lease structure of office buildings across Trepp NOI sample can help us better understand the dynamics of income and expense in green buildings. As mentioned in previous chapters, in general there are two types of lease contracts available for office tenants in the U.S., namely full service gross leases (gross) and triple net leases (NNN). In a gross lease[59], the lessee pays a flat rent and the lessor is responsible for all operating expenses. In a triple net[60] lease arrangement, the lessee pays a base rent and is responsible for all expenses associated with their proportional share of occupancy of the building.

Table 9 demonstrates notable differences in terms of proportions of properties in each sample that are let on NNN lease basis compared to gross leases. In the green sample with, 302 observations across five MSAs, there are 56 green buildings with NNN leases compared to 246 that are on gross leases. This means that only 19 percent of office buildings in the treatment sample are let on a triple net base lease. In the conventional sample with 2,160 observations across five MSAs, there are 373 office buildings on NNN lease compared to 1,787 with gross leases. Triple net lease therefore, represents only 17 percent of the control sample. With 27 percent net lease in green sample, Chicago (12 out of 45) and Washington DC (19 out of 70) show the highest proportion of net lease across

[59] In gross leases, landlords are responsible for all operating expenses, with taxes, maintenance, insurance and utilities being already included in the gross rent.
[60] In triple net leases, tenants are responsible for their proportionate share of property taxes, property insurance, common operating expenses and common area utilities. In addition, tenants are responsible for all costs associated with their own occupancy including personal property taxes, janitorial services and utility costs.

five MSAs. With only 8 NNN lease out of 112 leases in green sample (representing 8 percent of total), New York has the lowest share of net leases across full Trepp NOI sample. Overall, gross leases constitute more than 80 percent of all leases (2,033 out of 2,462 observations) in both certified and non-certified samples and across all MSAs. Table 9 also shows that across 2,462 observations, both net operating income and total operating expenses in office properties with a gross lease are significantly higher compared to those properties let on a NNN basis lease. This holds true for both green and conventional samples within each MSA and across full sample.

With respect to lease structure[61], higher NOI and higher total OpEx in gross leases along with higher proportion of gross leases, is consistent with the expectation that landlords of office buildings are more inclined to offer gross leases. This observation is more significant in green buildings because, regardless of how efficiently tenants use the space, landlords can still take appropriate measures to reduce the overall maintenance and operation costs (thus capturing operating cost savings) while maximizing their profit through setting a flat rent that is usually higher than market rates. More thorough investigation is required to provide empirical evidence to explain these observations as higher share of gross leases and higher OpEx in buildings let on gross leases may simply be reflective of differences in property types (e.g. single tenanted vs. multi-tenanted) and/or market demand (e.g. tenant preference) between the certified and non-certified samples.

[61] Different lease structures provide different incentives for lessors and lessees concerning the efficient use of the building. In gross leases lessors have an incentive to implement energy efficiency measures, because they directly benefit from the resulting savings. Gross leases, however, offer no incentive for lessees to use space efficiently. In net leases, lessees have an incentive to use space efficiently, because they directly benefit from energy savings. However, in this lease arrangement the lessor has no incentive to invest in energy efficient measures.

Table 9: Net Operating Income and Operating Expenses by Market by Lease Structure and Green Designation

		Green			Conventional		
		Type of Lease			Type of Lease		
Market		**Gross**	**NNN**	**Total**	**Gross**	**NNN**	**Total**
Boston	NOI	31.04	20.81	28.49	23.21	13.96	20.82
	OPEX	14.28	9.57	13.1	10.68	6.42	9.58
	Freq.	18	6	24	129	45	174
Chicago	NOI	20.11	8.67	17.06	15.89	7.72	13.87
	OPEX	12.07	5.2	10.24	9.53	4.63	8.32
	Freq.	33	12	45	241	79	320
New York	NOI	40.42	7.52	38.07	29.44	9.15	28.38
	OPEX	29.91	5.57	28.17	21.79	6.77	21
	Freq.	104	8	112	758	42	800
San Francisco	NOI	33.55	10.41	28.56	29.86	8.14	25.65
	OPEX	17.11	5.31	14.56	15.23	4.15	13.08
	Freq.	40	11	51	295	71	366
Washington	NOI	39.23	16.79	33.14	27.32	18.36	24.89
	OPEX	30.2	12.93	25.51	21.04	14.14	19.16
	Freq.	51	19	70	364	136	500
Total	NOI	35.64	12.9	31.43	26.8	12.6	24.35
	OPEX	24.35	8.36	21.39	18.1	8.46	16.43
	Freq.	246	56	302	1787	373	2160

5.1.2 Descriptive Statistics: RCA MV Sample

Table 10 provides summary statistics describing average quantities for market value, age, rentable building area, building height and cap rate with respect to certified and non-certified office buildings for the full RCA MV sample across five MSAs. From the data presented in Table 10 it can be observed that on average green buildings are younger, considerably larger and slightly shorter suggesting that they are mainly located in central business district locations. These findings reinforce similar results documented in current literature (Miller et al., 2008; Eichholtz et al., 2009a; Pivo and Fisher, 2010; Wiley et al., 2010; Fuerst and McAllister, 2011b; Chegut et al., 2013; Bond and Devine, 2016 among others). Without controlling for the differences between building hedonic characteristics, geographic location and market conditions, it can be observed that, on average green buildings transact at lower cap rates (5.05 percent for green and 5.38 percent for conventional) and higher market values ($649.80 for green and $497.89 for conventional) compared to their average conventional counterparts. Similar results can be observed in each of the five MSAs and across the entire RCA MV sample of 7,420 office space.

5.1.3 Analysis of Market Value, NOI and Cap Rate Interaction

In the context of existing literature, the most direct evidence of a link between sustainability and property market value is an observed change in a property's NOI.

Table 10: Summary Statistics by Market by Green Designation – RCA MV Sample

Market	Market Value ($/SF)			Age (Yrs.)			RBA (1000 SF)[*]		
	Green	Conventional	Total	Green	Conventional	Total	Green	Conventional	Total
Boston	630.64	425.88	450.7	32.25	37.3	34.75	362.17	267.35	287.4
Chicago	294.86	184.51	198.11	82.08	94.1	92.61	74.86	89.22	81.92
New York	807.24	673.52	689.94	46.35	62.34	59.56	859.25	523.45	560.23
San Francisco	638.88	515.1	530.24	43.74	54.35	54.28	265.87	172.56	179.85
Washington	640.57	429.91	455.78	30	39.92	38.7	317.29	184.37	210.89
Total	649.8	497.89	516.53	46.39	56.36	54.78	475.66	287.78	321.25

Market	Stories[**]			Cap Rate[***]			Observations		
	Green	Conventional	Total	Green	Conventional	Total Sample	Green	Conventional	Total
Boston	23.25	32.07	31.37	4.7	5.01	4.97	910	6,510	7,420
Chicago	28.13	33.67	33.57	5.9	7.59	7.38			
New York	31.07	29.93	31.05	4.8	4.38	4.43			
San Francisco	27.45	28.56	24.58	4.6	5.1	5.04			
Washington	11.21	10.94	10.98	5.36	5.89	5.83			
Total	25.45	26.37	24.58	5.05	5.38	5.34			

[*] Chicago is the only exception where conventional buildings offer about 15,000 SF larger RBA on average compared to green buildings.
[**] New York and Washington DC are the only exceptions where green buildings are slightly taller on average relative to their conventional counterparts.
[***] New York is the only exception in terms of showing lower cap rates in conventional office building stock.

It is widely believed among industry professionals that the capitalization rate[62] is the most appropriate tool in identifying the relationship between net operating income and market value in commercial real estate assets[63]. It is worth noting that these three economic performance determinants are tightly intertwined. On the one hand, if it is the case that green buildings generate more net operating income, the resulting higher market values should logically lead to lower cap rates (i.e. lower risk investment vehicle). On the other hand, with NOI being held constant, lower cap rates would be translated into higher values in green buildings (i.e. higher return investment vehicle). I explain these observations through two quantitative analysis that follows.

First, consider the average net operating income for the green buildings in Trepp NOI sample of office buildings which is $31.43 per square foot. This amount for conventional buildings in the same sample is $24.35 per square foot. At average size of buildings within the entire Trepp NOI sample which is 318,000 square foot, the estimated annual net operating income increment is approximately 2.25 million dollars (($31.43-$24.35)*318,000) for a green building. All else being equal, the average market value for the green buildings in the RCA MV sample of building sold in the 2010-2015 period is $649.80 per square foot. At the average capitalization rate of 5.05 for green buildings, net operating income is $32.81 per square foot. The average market value for the control buildings in the RCA MV sample of building sold in the 2010-2015 period is $497.89 per square foot. At the average capitalization rate of 5.38 for conventional buildings, net

[62] Widely used in commercial property valuation, cap rate is the rate of return or risk premium of an investment.

[63] Traditional valuation methods for the assessment of commercial property values are based on discounted cash flow which incorporates gross annual income and operating expenses to arrive at net operating income. Market value in each location may be calculated by dividing NOI by prevailing cap rate in that location. This method is described fully in Chapter 2.

operating income is $26.78 per square foot. At average size of buildings within the entire RCA MV sample which is 321,000 square foot, the estimated annual net operating income increment is approximately 2 million dollars (($32.81 -$26.78)*321,000) for a green building. These findings suggest that the effects of sustainability features (i.e. LEED and Energy Star certifications) on NOI are being capitalized into market values.

Second, a more holistic way to investigate the consistency of statistical results to determine NOI and MV across all models, is to run these numbers across the entire datasets to include both treatment and control samples. Ceteris paribus, the average NOI for Trepp's total 2,462 observations is $25.22 per square foot. For a typical building in Trepp NOI sample with an average size of 318, 000 square foot, the annual NOI is approximately, $8 million. On the other hand, the average market value for the entire 7,420 0bservations in RCA dataset is $516.53 per square foot. At a prevailing capitalization rate of 5.34 percent, net operating income for a typical building is $27.58 per square foot. For a typical building in the RCA sample with an average size of 321, 000 square foot, the annual NOI is approximately, $7.9 million. This is another indication of the accuracy of the income capitalization method and the statistical analysis provided in this study.

Figure 5 below shows average values for log NOI, log MV and cap rates for green and conventional office buildings stock in each metropolitan area and across five MSAs. It confirms the calculations and attest to the fact that both higher NOI and lower cap rates contribute to value premiums. This figure clearly depicts that on average green buildings generate more income and transact at higher market values. It also shows that aside from New York, cap rates in every other metropolitan area and across full sample are smaller for green buildings.

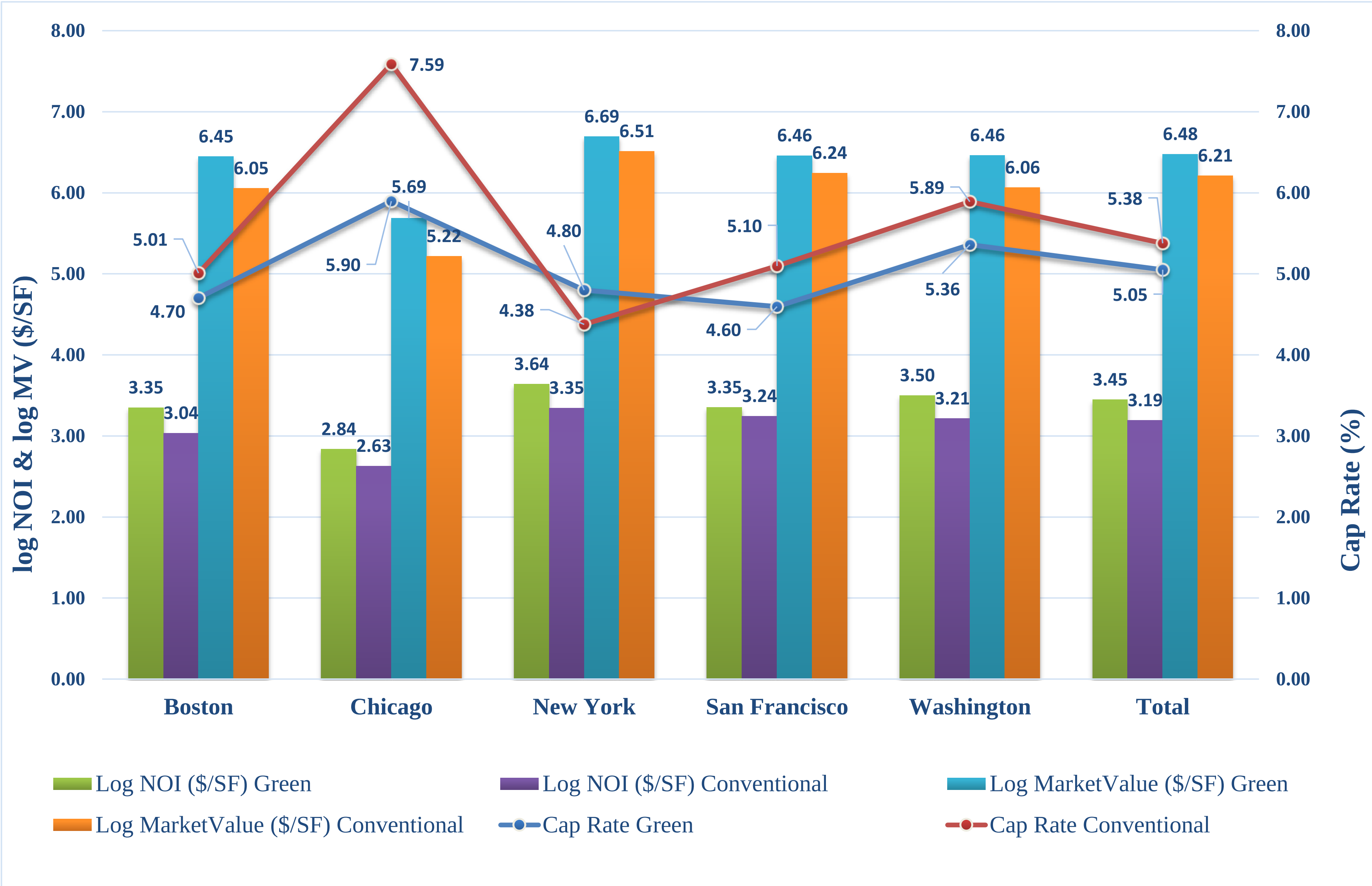

Figure 5: log NOI, log MV and Cap Rates in Green and Conventional Stock of Office Buildings across Five MSAs

5.2 Data Analysis: Regression Analysis

Before I turn to regression analysis, it is important to investigate the correlation between variables in both Trepp and RCA samples to ensure that my data meets the underlying assumptions of the hedonic models and that statistical analyses is based on a solid foundation. After an analysis of correlation matrices, and to further investigate the hypothesis of a premium for income and value in green buildings, I estimate hedonic regressions as outlined in Chapter 5, analyze empirical findings and fully discuss regression results in the subsections that ensue.

5.2.1 Correlation Matrices: Trepp NOI and RCA MV

This section provides three correlation matrices demonstrating information that helps investigate the relationship between dependent and independent variables defined in this study. The correlation matrices are accompanied by a detailed interpretation of findings. An important assumption for the hedonic regression model is that independent variables are not perfectly multicollinear, meaning that one independent variable should not be a linear function of another[64]. All variables of this study have been chosen carefully to avoid the problem of multicollinearity. That is to say that none of the independent variables are proxies for one another.

Tables 11 below provides the correlation[65] matrices between the independent and dependent variables. As it can be seen in Table 11, there is a strong positive correlation between logarithm net operating income and logarithm market value, and rentable building area (0.32 and 0.43), class A building quality (0.40 and 0.36), proximity to transit (0.35

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[64] When multicollinearity is present standard errors may be inflated.

[65] Pearson correlation coefficients, go from -1 to 1; closer to 1 means strong correlation. A negative value indicates an inverse relationship meaning when one variable goes up the other goes down.

and 0.31) and presence of building amenities (0.30 and 0.24) suggesting that these hedonic characteristics positively impact income and value in office buildings across five MSAs. The table also shows a negative correlation between log NOI and log MV, and building age (-0.35 and -0.33), height (-0.05 and -0.02), and presence of building renovations (-0.09 and -0.08). It is interesting to observe that variables ‘renovated’ and ‘age’ show a positive and significant correlation of 0.61. *A priori* inference suggests that because major renovations usually take place in older buildings, there is a negative correlation between log NOI and log MV and aged/renovated buildings. As anticipated log NOI demonstrates a significant and negative correlation with triple net lease structure (-0.63) confirming the observation that office buildings let on gross leases basis generate more income for landlords. Surprisingly, there is also a positive albeit weak and insignificant correlation of 0.05 between log NOI and building occupancy levels suggesting the minuscule role it plays in generating more income. This finding supports the popularly held belief and presumed notion among real estate industry professionals that buildings that command higher rents should expect lower occupancy rates.

Table 12 demonstrates the correlation between all determinants of economic performance discussed in this study across five MSAs and for the full sample of both data sets (i.e. 2,462 Trepp NOI plus 7,420 RCA MV observations). As expected, there is a strong positive correlation between NOI and MV and rents achieved by office properties (almost 100 percent and 93 percent, respectively). There is also a strong and significant correlation between NOI and MV (0.93) which provides further evidence for the influence NOI can exert on market value. *Inter alia*, as expected from the results previously described in descriptive statistics, there appears to be a strong and positive correlation between NOI and OpEx. As expected, cap rate has a strong negative and significant correlation with market value suggesting that, ceteris paribus, lower cap rates lead to higher valuations of real estate assets.

Finally, Table 13 clearly shows that both dependent variables in the statistical models, (i.e. log NOI and log MV) are strongly and positively correlated with all types of certification categories defined in this study with LEED (0.29 for log NOI and 0.25 for log MV) and dual (0.28 for log NOI and 0.24 for log MV) certification showing highest levels of positive correlation. The correlation is significant and positive but less strong with Energy Star (0.06 for log NOI and 0.07 for log MV) and green (0.07 for log NOI and 0.08 for log MV) categories of certification type. As expected, LEED shows a very strong influence on Dual at 0.97 and a less strong but positive impact on green at 0.62.

In the following two sections, I turn to regression analyses to determine whether expected signs and significance provided by descriptive statistics and correlation matrices can be actually observed and verified in hedonic models.

Table 11: Correlation Matrix for Dependent and Independent Variables

	Log NOI	Log MV	Age	RBA	Stories	Class A	NNN	Transit CBD	Amenities	Renovated	Occupancy
Log NOI	1										
Log MV	0.9348***	1									
Age	-0.355***	-0.335**	1								
RBA	0.317***	0.429***	-0.0949***	1							
Stories	-0.0504*	-0.0233	0.144***	0.138***	1						
Class A	0.402***	0.360***	-0.187***	0.230***	0.000956	1					
NNN	-0.634***	N/A	0.113***	-0.216***	-0.0626**	-0.218***	1				
Transit CBD	0.350***	0.312***	-0.0410*	0.0919***	0.0994***	0.174***	-0.483***	1			
Amenities	0.304***	0.241***	-0.104***	0.0945***	0.00285	0.682***	-0.230***	0.188***	1		
Renovated	-0.0920***	-0.082***	0.611***	0.0395*	0.0926***	0.139***	-0.0196	0.0550**	0.207***	1	
Occupancy	0.0507*	N/A	-0.0358	0.0466*	0.0154	0.032	-0.0112	-0.0111	0.0315	0.022	1

*significant at the 10 percent level (p<0.05)
**significant at the 5 percent level (p<0.01)
***significant at the 1 percent level (p<0.001)

Table12: Correlation Matrix for Economic Performance Metrics

	Rent	Occupancy	NOI	OPEX	MV	Cap Rate
Rent	1					
Occupancy	0.0438*	1				
NOI	0.995***	0.0555**	1			
OPEX	0.976***	0.021	0.967***	1		
MV	0.929***	N/A	0.933***	0.904***	1	
Cap Rate	-0.241***	-0.0760***	-0.251***	-0.245***	-0.524***	1

Table 13: Correlation Matrix for Dependent Variables and Type of Certification Category

	Log NOI	Log MV	LEED	EnergyStar	Dual	Green
Log NOI	1					
Log MV	0.9348***	1				
LEED	0.292***	0.249***	1			
EnergyStar	0.0636**	0.0735***	0.584***	1		
Dual	0.280***	0.240***	0.970***	0.605***	1	
Green	0.0757***	0.0830***	0.616***	0.987***	0.597***	1

*significant at the 10 percent level (p<0.05)
**significant at the 5 percent level (p<0.01)
***significant at the 1 percent level (p<0.001)

5.2.2 Regression Analysis: Net Operating Income (NOI)

As mentioned before, I use log transformed[66] dependent variables in all models to reduce skewness and facilitate interpretability of the coefficients[67]. Table 14 presents the overall results for the Trepp NOI sample, relating the natural logarithm of net operating income per square foot in commercial office buildings to a set of hedonic and other characteristics of those buildings. Results are presented for ordinary least squares (OLS) regression models corrected for heteroscedasticity. The OLS regression analysis has the advantage of controlling for a number of omitted variables (e.g. small scale spatial submarket specifics) that could not be modeled explicitly. Column (1) reports a basic model relating NOI to building quality, measured by class designation, lease type and rentable building area (RBA) in thousands of square foot. The regression, based upon 2,462 observations on buildings across five metropolitan area explains some 69 percent of logarithm NOI. As expected, and consistent with my findings in descriptive statistics section, when rents are quoted gross, the NOI is about 8 percent higher than when they are quoted net of utilities (NNN). Higher quality buildings, as measured by building class, command a substantial premium. Net operating income in class A building is about 34 percent higher than in a class C building and about 11 percent higher than in a class B building. NOI appears to be slightly higher in larger buildings, as measured by square footage. However, the magnitude is quite small, about 1 percent for an additional 100,000 square foot. Employment growth in the service sector demonstrates a strong effect on net

[66] A set of comparative charts depicting difference in normality between NOI and log NOI is presented at the end of this chapter in section 5.2.4 Sensitivity Analysis: Post Regression Diagnostic Tests.

operating income, a 10 percent increase in employment in the service sector leads to an increase of 6.4 percent in NOI.

With an F-value of 133.82, representing an associated P-value of 0.0000, the coefficients for the 302 dummy variables for location are highly significant. This means that the group of independent variables herein discussed reliably predict the dependent variable, log NOI, of commercial office buildings across five MSAs. More importantly, the result of this statistical model clearly shows that, ceteris paribus, the estimated NOI premium for a green building (LEED or Energy Star certified) is about 7.8 percent.

In column (2), the green ratings is distinguished by its Energy Star or LEED certification. Both LEED and Energy Star certifications are found to have positive and significant impacts on NOI. The estimated coefficient for the LEED rating indicates a significant premium of 22.1 percent in NOI in commercial office properties tied to CMBS loans. The difference between LEED and Energy Star income premiums is of high significance. The Energy Star rating is only associated with net operating incomes higher by 3.2 percent. Due to the data specifications in this research, these coefficients have a very straightforward interpretation for the impact of green building on the market dynamics of commercial real estate office assets suggesting that LEED certified buildings generate more income.

In column (3), a set of variables measuring building age in five categories is added to the model. The coefficient of the other variables are quite stable and remain within a similar range. As expected, the results indicate that there is a substantial premium associated with newer buildings. With all else being equal, NOI in a commercial building less than ten years old is nearly 40 percent higher than those in a building more than 50 years old.

Column (4) adjust for differences in building height[68], proximity to public transit, major renovations, occupancy rates, and for the presence of onsite amenities. Contrary to my expectation that high rise office buildings generate more income -- by commanding more rents and benefiting from higher occupancy rates -- it is evident from the results that very tall buildings (higher than 20 stories) bring in lower net operating income. As expected, the presence of building amenities onsite and proximity to public transportation are associated with higher net operating income. Surprisingly, although positive, higher occupancy rates' contribution to NOI is very insignificant. This confirms the weak correlation between these two variables discussed earlier in this chapter. Unexpectedly, renovated buildings too offer lower NOI. This evidence could be explained by the fact that renovated properties are normally aged and therefore earn lower income. This finding also confirms the negative correlation between NOI and renovated variables. As can be seen in columns (1), (3) and (4), when the specification of the hedonic variables is changed in various ways, the magnitude and statistical significance of the green rating is unchanged. The result of this regression model suggests that, Ceteris paribus, the NOI in certified buildings is significantly higher by 7.6 to almost 8 percent compared to comparable non-certified building in the same submarket.

In column (5), the green ratings is distinguished by its dual certification under both LEED and Energy Star schemes. A complete set of independent variables as added to column (4) are included in column (5) to analyze and investigate the impact of dual

[68] Number of stories is used as a proxy for building height in this dissertation.

certification as well as other building hedonic characteristics on NOI in office buildings. The estimated coefficient for dual certification indicates a significant premium of 21.7 percent in NOI in office properties tied to CMBS loans. As was the case with columns (1) and (2), higher quality buildings, as measured by building class, command a substantial premium in column (5) too. With dual certification being present in a building, net operating income in class A building is about 31 percent higher than in a class C building and about 11 percent higher than in a class B building. When rents are quoted gross, NOI is about 12 percent higher than when they are quoted net of utilities (NNN). The coefficient of other variables are quite stable and remain within a similar range as in column (4).

Table 14: Basic Regression Results, Commercial Buildings Net Operating Income (NOI) and Green Ratings (*dependent variable: natural logarithm of NOI in dollars per square foot*)					
	(1)	(2)	(3)	(4)	(5)
Green Rating					
LEED or Energy Star (1=Yes)	0.0782**		0.0765**	0.0799***	
	(0.0304)		(0.0296)	(0.0298)	
LEED (1=Yes)		0.221***			
		(0.0406)			
Energy Star (1=Yes)		0.032***			
		(0.02980)			
Dual Certification (1=Yes)					0.217***
					(0.0416)
Building Class					
Class A (1=Yes)	0.338***	0.278***	0.288***	0.268***	0.308***
	(0.0196)	(0.02610)	(0.0262)	(0.0262)	(0.0270)
Class B (1=Yes)	0.228***	0.173***	0.168***	0.148***	0.198***
	(0.0296)	(0.0278)	(0.0346)	(0.0276)	(0.0276)
Lease Type					
NNN (1=Yes)	-0.082***	-0.109***	-0.081***	-0.081***	-0.121***
	(0.0270)	(0.0258)	(0.0256)	(0.0280)	(0.0280)
Employment growth (Fraction)	0.638***	0.603***	0.618***	0.626***	0.646***
	(0.0196)	(0.0186)	(0.0262)	(0.0262)	(0.0272)
Building Age					
1 to 10			0.393***	0.249***	0.259***
			(0.0426)	(0.0469)	(0.0469)
11 to 20			0.266***	0.229***	0.219***
			(0.0257)	(0.0292)	(0.0292)
21 to 30			0.213***	0.179***	0.179***
			(0.0249)	(0.0278)	(0.0278)
31 to 40			0.119***	0.0897***	0.0897***
			(0.0191)	(0.0219)	(0.0219)
41 to 50			0.143***	0.049***	0.059***
			(0.0203)	(0.0230)	(0.0230)
Building Height					
Intermediate (1=Yes)				0.0931*	0.1131*
				(0.02920)	(0.0220)
Tall (1=Yes)				0.075***	0.075***
				(0.0305)	(0.0305)
Building Qualities					
RBA (100K of SF)	0.01279***	0.01482***	0.01328***	0.01331***	0.01331***
	(0.000044)	(0.000041)	(0.000043)	(0.000043)	(0.004300)

Amenities (1=Yes)				0.0478*	0.0597*
				(0.023300)	(0.0233)
Proximity to Transit (1=Yes)				0.105***	0.1235***
				(0.030900)	(0.0310)
Renovated (1=Yes)				-0.0415*	-0.0525*
				(0.018800)	(0.0188)
Occupancy (%)				0.00214*	0.00454*
				(0.000875)	(0.0009)
Constant	3.213***	2.795***	3.259***	2.990***	3.0990***
	(0.016300)	(0.017500)	(0.032900)	(0.090500)	(0.0905)
Submarket Controls	Included	Included	Included	Included	Included
Observations	2,462	2,462	2,462	2,462	2,462
R-squared	0.695	0.681	0.682	0.694	0.734
Adjusted R-squared	0.674	0.664	0.653	0.669	0.716

Notes: each regression also includes 302 dummy variables, one for each locational cluster. Standard errors are in parentheses.
*significant at the 10 percent level (p<0.05)
**significant at the 5 percent level (p<0.01)
***significant at the 1 percent level (p<0.001)

Table 15 explains the variation in the dependent variable, natural logarithm of net operating income per square foot, in each market and in total across all observations in five MSAs for Trepp NOI sample. The qualitative results are similar to what was observed in the preliminary statistical model for NOI with five columns presented in Table 14 above. Across five MSAs, based upon 2,462 observations on office buildings, the regression explains some 69 percent of log NOI. All in all, in each individual MSA and across all markets, the group of dependent variables (hedonic characteristics and other building features) included in this statistical model suggest great strength of association with dependent variable (natural logarithm of NOI). Explaining some 87% of log NOI, based on total of 417 observations, this association appears to be strongest in San Francisco commercial real estate market place. With that being said, the focus here is on the significance of the green variable and not the predictive power of the models. In all models, certification appears to provide higher NOI and MV per square foot than conventional office buildings.

For each of the specifications reported in the models in each market, the variable reflecting certification of a green building is somewhat significant with the full sample's being highly significant. With some variations in each market, the income premiums for green buildings are, ceteris paribus, higher than for conventional buildings. While this premium, at lowest, is about 3.8 percent in San Francisco, it is twice as much in Washington D.C. and New York (nearly 9 percent) and Chicago (7.8 percent). When controlling for differences across regional markets, lease types and building characteristics, green buildings achieve a premium NOI ranging from 3.8 percent (San Francisco) to 11.7 percent (Boston) relative to their comparable non-green counterparts. In total and across full sample of five MSAs there is a highly significant 8 percent premium in NOI for green buildings.

There is some evidence that net operating income per square foot is higher for a class A building with the total five market sample showing a 27 percent premium compared to class C and almost 12 percent premium compared to a class B building. Across five MSAs, when rents are quoted gross, they are about 8 percent higher than when they are quoted net of utilities. New York and Chicago show lowest and highest difference between gross and net leases income (9 percent and 14 percent) among all MSAs, respectively. Employment growth in the service sector demonstrates a strong effect on net operating income, a 10 percent increase in employment in the service sector leads to an increase of 6.4 percent in NOI across all MSAs. The effect is of lowest magnitude in Chicago and highest magnitude in Washington D.C. These observations can be verified by the higher overall unemployment rates[69] in Chicago and greater degree of emigration of young professionals and blue collar workers to Washington D.C. metro area between 2005 and 2010.

The results also indicate that there is a substantial premium associated with newer buildings. With all else being equal, across the entire sample, NOI in a commercial building less than ten years old is nearly 25 percent higher than those in a building more than 50 years old. A similar pattern can be observed in each individual market. The higher NOI in younger buildings could be attributed more to higher rents as the newer buildings tend to have higher vacancy rates. Older properties generate lower NOI, but they are more likely to show higher occupancy levels due to having established tenants with long-term leases.

[69] These data are available from the Bureau of Labor Statistics (https://data.bls.gov).

From the table, it can also be construed that buildings with fewer stories (intermediate height[70]) generate more income per square foot. Although insignificant, rentable building area shows slightly larger premiums in Boston and New York with 5 percent and 4 percent, respectively. NOI appears to be slightly higher in larger buildings, as measured by square footage. However, the magnitude is quite small, about 1 percent for an additional 100,000 square foot across five MSAs.

The result also suggests that buildings offering onsite amenities (4.8 percent) provide owners/investors with higher revenues. Proximity to CBD transit is also used as a proxy to control whether or not a property is in a CBD and has access to transit hubs in a downtown area. As expected, proximity to transit stations is also associated with significantly higher net operating income (10 percent across all observations). This is primarily due to the fact that a building with high quality design standing in a preeminent downtown location have an improved ability to generate more income. Such a property maximizes occupancy levels through attracting more established tenants while exploiting the intensity of demand and commanding higher rents. Lack of proximity to public transit and being located in a less desirable location, makes it difficult for a building to attract more stable tenants. To maintain higher occupancy rates, owners of such buildings are forced to offer lower than market rate rents, thus lowering their net operating income.

Consistent with prior findings, renovated buildings seem to offer lower NOI in each individual market as well as across full sample. This lower income is mainly caused by the older age of buildings are undergoing substantial renovations in order to maintain their relevance and remain competitive among their younger or green peers. In terms of ability

[70] With more than 10 and less than 20 stories.

to generate higher income, it can be observed from the data that renovated older buildings suffer most in New York which explains the appeal of younger buildings aged less than 10 to investors (please refer to coefficient for building age 1 to 10 for New York - 27 percent - in regression table) and new construction to developers in this market. As expected and discussed before, although positive, higher occupancy rates' contribution to NOI is minuscule and insignificant. According to the empirical model, for every 10 percent increase in occupancy rates, net operating income only increases by 2 percent and the relationship is only significant at 10 percent level across all five MSAs. None of the reported occupancy observations appear to be significant in any of the individual markets.

It should be noted that the inclusion of the constant term in the statistical models herein described provides an intercept to the line of predicted values, rather than assuming an intercept of zero. The result is a model with a much better fit because it minimizes the sum of squared errors and therefore, parameter estimates become much more accurate.

Table 15: Regression Results, Commercial Office Buildings NOI and Green Ratings, Five MSA (2005-2015) Trepp NOI Sample (*dependent variable: natural logarithm of Net Operating Income in dollars per square foot*)						
Market	**Boston**	**Chicago**	**New York**	**San Francisco**	**Washington DC**	**Total**
Green Rating						
LEED or Energy Star (1=Yes)	0.1172***	0.0788**	0.0873**	0.0378*	0.0891**	0.0799***
	(0.02710)	(0.03970)	(0.03360)	(0.05550)	(0.04550)	(0.02980)
Building Class						
Class A (1=Yes)	0.2607***	0.239***	0.2701***	0.336***	0.229*	0.268***
	(0.05000)	(0.05090)	(0.08190)	(0.05000)	(0.04740)	(0.02620)
Class B (1=Yes)	0.128***	0.143***	0.178***	0.218***	0.168***	0.148***
	(0.02960)	(0.02780)	(0.03460)	(0.02760)	(0.02330)	(0.02760)
Lease Type						
NNN (1=Yes)	-0.106*	-0.142***	-0.091***	-0.114***	-0.131***	-0.081***
	(0.05220)	(0.03040)	(0.06330)	(0.05800)	(0.03440)	(0.02800)
Employment growth (Fraction)	0.438***	0.296***	0.318***	0.546***	0.648***	0.626***
	(0.01960)	(0.01860)	(0.02620)	(0.02620)	(0.02620)	(0.02620)
Building Age						
1 to 10	0.206*	0.241***	0.273***	0.181**	0.112***	0.249***
	(0.12600)	(0.12800)	(0.32700)	(0.12200)	(0.02990)	(0.04690)
11 to 20	0.1496	0.1617***	0.2361***	0.125	0.102***	0.229***
	(0.06510)	(0.07150)	(0.07170)	(0.08820)	(0.02670)	(0.02920)
21 to 30	0.1435	0.1487***	0.113**	0.0533	0.0895**	0.179***
	(0.08060)	(0.05460)	(0.03820)	(0.10100)	(0.03310)	(0.02780)
31 to 40	0.0848	0.0867	0.0903***	0.0727	0.0485	0.0897***
	(0.05700)	(0.05310)	(0.02680)	(0.07910)	(0.03260)	(0.02190)
41 to 50	0.0285	0.0339	0.0620*	0.0329	0.0279*	0.049***
	(0.08410)	(0.05520)	(0.02440)	(0.08460)	(0.02720)	(0.02300)
Building Height						
Intermediate (1=Yes)	0.131*	0.0666	0.0429	0.0117	0.100***	0.0931*
	(0.06380)	(0.06320)	(0.09540)	(0.05660)	(0.02520)	(0.02920)
Tall (1=Yes)	0.0955	0.0577	0.0399	0.0245	-	0.075***
	(0.06140)	(0.06430)	(0.09500)	(0.05560)	-	(0.03050)

Building Qualities						
RBA (100K of SF)	0.0542	0.0115	0.0432	0.0104	0.0124***	0.01331***
	(0.00080)	(0.00250)	(0.00060)	(0.00140)	(0.00430)	(0.00430)
Amenities (1=Yes)	0.0180***	0.0342***	0.0507***	0.0357***	0.0578*	0.0478*
	(0.03490)	(0.02010)	(0.08910)	(0.02060)	(0.02330)	(0.02330)
Proximity to Transit (1=Yes)	0.1245***	0.1316***	0.1245***	0.1562***	0.125***	0.105***
	(0.06580)	(0.03540)	(0.05450)	(0.08500)	(0.03090)	(0.03090)
Renovated (1=Yes)	-0.0368	-0.0105	-0.042	-0.0713	-0.0425*	-0.0415*
	(0.04950)	(0.02250)	(0.02410)	(0.07840)	(0.01880)	(0.01880)
Occupancy (%)	0.00669	0.00297	0.00202	0.00855	0.00314*	0.00214*
	(0.00226)	(0.00118)	(0.00117)	(0.00157)	(0.00088)	(0.00088)
Constant	2.769***	2.459***	3.0158***	3.104***	2.986***	2.990***
	(0.21200)	(0.13400)	(0.15100)	(0.20000)	(0.10700)	(0.09050)
Submarket Controls	Included	Included	Included	Included	Included	Included
Observations	198	365	912	417	570	2,462
Green	24	45	112	51	70	302
R-squared	0.688	0.789	0.647	0.867	0.607	0.694
Adjusted R-squared	0.662	0.781	0.622	0.855	0.597	0.669

Notes: each regression also includes dummy variables equal to the number of green observations (e.g. 24 in Boston, 45 in Chicago, 112 in New York and 302 in total), one for each locational cluster. Standard errors are in parentheses.
*significant at the 10 percent level ($p<0.05$)
**significant at the 5 percent level ($p<0.01$)
***significant at the 1 percent level ($p<0.001$)

5.2.3 Regression Analysis: Market Value (MV)

Table 16 presents analogous results based upon the sample of 910 certified office buildings and/or space sold in the 2010-2015 period and the control sample of 6,510 non-certified office buildings and/or space sold within the same RCA submarket and within the 0.20 mile radius of those green properties. Results are presented for OLS regression models corrected for heteroscedasticity. These market value models explain the variation in the dependent variable, natural logarithm of market value per square foot, in each market and in total across all observations in five MSAs. Locational indicator variables are included in the model to control for fixed-price differences across five markets. The qualitative results are similar to what was observed in the statistical model for NOI for five MSAs in a previous section. Across five markets, based upon 7,420 observations on buildings, the regression explains some 61 percent of log MV. All in all, in each individual MSA and across all markets, the group of dependent variables (hedonic characteristics and other building features) included in this statistical model provide great strength of association with dependent variable (log MV). Explaining some 83% of log MV, based on total of 1,398 observations this association appears to be strongest in San Francisco commercial office real estate market place. For each of the specifications reported in the models and for each individual market, the variable reflecting certification of a green building (LEED or Energy Star) is significant with the full sample's being highly significant. With some variations in each market, the transaction premiums for green buildings are, ceteris paribus, higher than for non-certified buildings. While this premium is about 3.8 percent in New York and San Francisco, it is more than double in Washington DC (nearly 8 percent) and Chicago (9.4 percent).

Table 16: Regression Results, Commercial Office Buildings MV and Green Ratings, Five MSA (2010-2015) RCA MV Sample
(*dependent variable: natural logarithm of Market Value in dollars per square foot*)

Market	**Boston**	**Chicago**	**New York**	**San Francisco**	**Washington DC**	**Total**
Green Rating						
LEED or Energy Star (1=Yes)	0.0698**	0.0942**	0.0382**	0.0378***	0.0793***	0.0465***
	(0.0989)	(0.0440)	(0.0717)	(0.0656)	(0.0787)	(0.0357)
Building Class						
Class A (1=Yes)	0.479***	0.269***	0.498***	0.414***	0.260**	0.315***
	(0.0612)	(0.0545)	(0.0975)	(0.0584)	(0.0513)	(0.0327)
Class B (1=Yes)	0.369***	0.199***	0.348***	0.254***	0.115**	0.199***
	(0.0312)	(0.0465)	(0.0785)	(0.0523)	(0.0534)	(0.0347)
Building Age						
1 to 10	0.2543**	0.2801***	0.3581***	0.2647	0.2963**	0.327***
	(0.186)	(0.157)	(0.287)	(0.164)	(0.0348)	(0.0518)
11 to 20	0.1282	0.1700***	0.234***	0.1372	0.1897**	0.226***
	(0.0753)	(0.0930)	(0.0744)	(0.102)	(0.0312)	(0.0341)
21 to 30	0.0921	0.0899***	0.147**	0.0679	0.0825*	0.1149***
	(0.102)	(0.0593)	(0.0486)	(0.114)	(0.0369)	(0.0355)
31 to 40	0.0263	0.0117	0.129***	0.0549	0.0542	0.088***
	(0.0686)	(0.0555)	(0.0351)	(0.0928)	(0.0359)	(0.0277)
41 to 50	0.0909	0.0513	0.0883*	0.0450	0.0758*	0.0560***
	(0.107)	(0.0555)	(0.0350)	(0.0979)	(0.0326)	(0.0306)
Building Height						
Intermediate (1=Yes)	0.0808	0.123	0.189	0.0654	0.104***	0.0482
	(0.122)	(0.0825)	(0.139)	(0.0788)	(0.0283)	(0.0338)
Tall (1=Yes)	0.0736	0.106	0.159	0.0447	-	0.0184
	(0.121)	(0.0833)	(0.138)	(0.0777)	-	(0.0361)
Building Qualities						
RBA (100K of SF)	0.0871	0.0165	0.0501	0.0915	0.0136***	0.0698***
	(0.0928)	(0.0255)	(0.00572)	(0.0138)	(0.0276)	(0.0646)

Amenities (1=Yes)	0.088***	0.0632***	0.0581***	0.0868***	0.1139	0.0985***
	(0.0422)	(0.0232)	(0.0106)	(0.0251)	(0.0972)	(0.0299)
Renovated (1=Yes)	0.0729	0.0846	0.0982	0.1174	0.1130	0.1012***
	(0.0788)	(0.0417)	(0.0601)	(0.0905)	(0.0295)	(0.0349)
Transit Score (10 Points)	0.256*	0.317***	0.289***	0.380***	0.267***	0.312**
	(0.0538)	(0.0295)	(0.0391)	(0.0921)	(0.0933)	(0.0215)
Walk Score (10 Points)	0.276*	0.302***	0.319***	0.362***	0.233***	0.294**
	(0.0528)	(0.0487)	(0.0536)	(0.0716)	(0.0435)	(0.0362)
Constant	5.678***	4.775***	5.989***	5.836***	5.736***	5.624***
	(0.264)	(0.155)	(0.192)	(0.239)	(0.130)	(0.115)
Submarket Controls	Included	Included	Included	Included	Included	Included
Observations	718	1,387	1,873	1,398	2,044	7,420
Green	87	171	230	171	251	910
R-squared	0.638	0.787	0.554	0.832	0.601	0.612
Adjusted R-squared	0.608	0.778	0.547	0.826	0.591	0.6090

Notes: each regression also includes dummy variables equal to the number of green observations (e.g. 87 in Boston, 171 in Chicago, 230 in New York and 910 in total), one for each locational cluster. Standard errors are in parentheses.
*significant at the 10 percent level (p<0.05)
**significant at the 5 percent level (p<0.01)
***significant at the 1 percent level (p<0.001)

The MV premium in Boston shows 7 percent for green buildings compared to their conventional counterparts. In total there is a highly significant 4.6 percent premium in transactional prices for green buildings across five MSAs. The result of this study compares to a range of value premiums of 6 percent to 26 percent reported in other studies over the past decade. My findings fall into the lower range of other findings; nonetheless, they are consistent with the conclusion of every other study to date with respect to sales prices: there has been a significant value premium associated with green properties (Miller et al., 2008; Pivo and Fisher, 2010; Eichhotltz et al., 2009a; Fuerst and McAllister, 2011b; Chegut et al., 2013).There is some evidence that selling prices per square foot are higher for class A buildings with the full sample showing a 31 percent premium compared to class C and almost 11 percent premium compared to class B buildings. The results also indicate that there is a substantial premium associated with newer buildings. With all else being equal, across the entire RCA MV sample, selling prices in a commercial office building less than ten years old is nearly 33 percent higher than those in a building more than 50 years old. Similar pattern can be seen in each individual market with New York showing the highest sales premium at 36 percent among five gateway cities for office assets younger than 10 years compared those older than 50. The evidence that older properties are found to sell at a discount could be attributed to the anticipation of higher capital expenditures. Older properties might also be more likely to exist in an area that has transitioned and is no longer considered the most desirable part of the CBD.

From the table, it can also be observed that buildings with fewer stories (intermediate height) sell for higher prices per square foot[71]. Market value appears to be

[71] Washington DC' tallest buildings stand at 15 stories height and therefore there is no tall building in DC according the specifications of this hedonic model.

slightly higher in larger buildings, as measured by square footage. However, the magnitude is quite small, about 7 percent for an additional 100,000 square foot across five MSAs. The building size shows slightly larger premiums in Boston and San Francisco with 8.7 percent and 9.2 percent respectively. However, none of these reported observations appear to be significant. The result also suggests that buildings offering onsite amenities (9.8 percent) and renovated buildings (10 percent) sell with a substantial and significant premium. The result of MV statistical model also indicates that higher transit and walk scores lead to higher selling prices. For each additional 10 points, there is nearly 30 percent premium for walkability and 31 percent premium for accessibility to public transportation across all observations in five MSAs. This confirms the findings of previous research that if transit improves accessibility and urban design promote walkability (Pivo and Fisher, 2010; Kok and Jennen 2012), then properties near transit hubs and in walkable areas should generate more income and transact at higher selling prices. Interestingly, the market value premium for transit oriented properties is almost triple the NOI premium. This reinforces the notion that concerns about gas prices, carbon taxes, traffic congestion, and accessibility issues, along with forecasted growth in demand toward transit-oriented properties can shape what investors are willing to pay for less auto dependent CBD located properties in the future.

It should be noted that the results reported in all regression analysis tables above are robust to other variations in the hedonic characteristics included on the right hand side in the vector X as described in Model (1) and Model (2) in chapter 4. However, these results are not robust to the exclusion of the dummy variables identifying the locational clusters in which their sample and control properties are located.

These regression results suggest that the significant impact of certification on net operating income is also revealed in the asset market through a substantial market value premium for green buildings. From the findings it can be learned that, although sales data from RCA and rental data from Trepp samples are coming from two separate and distinct sources, the statistical results are broadly consistent across the models in each MSAs and within the entire sample of five metropolitan areas for the purpose of NOI and MV determination.

Figures 6 and 7 combine three scatterplots and their linear fit and overlay all that information in one graph. It displays distributions of cap rates against log NOI and log MV for all observations in Trepp NOI and RCA MV samples. These figures clearly show the relationship between NOI, MV and cap rates for certified and non-certified stock of office buildings in each of the five MSAs and across full sample. The blue (log NOI) and red (log MV) dots represent observations while the orange and green lines represent fitted value lines. It is worth noting that these lines stand higher in green category in each MSA and across full sample. These figures illustrate visually that there is clear evidence for NOI and MV premiums for green buildings in each metro and across five MSA. An inverse relationship between cap rate and MV is apparent in both figures which confirms the notion that green buildings transact at higher market value and lower cap rates. The distributions plotted here exhibit exact same information displayed in figure 5.

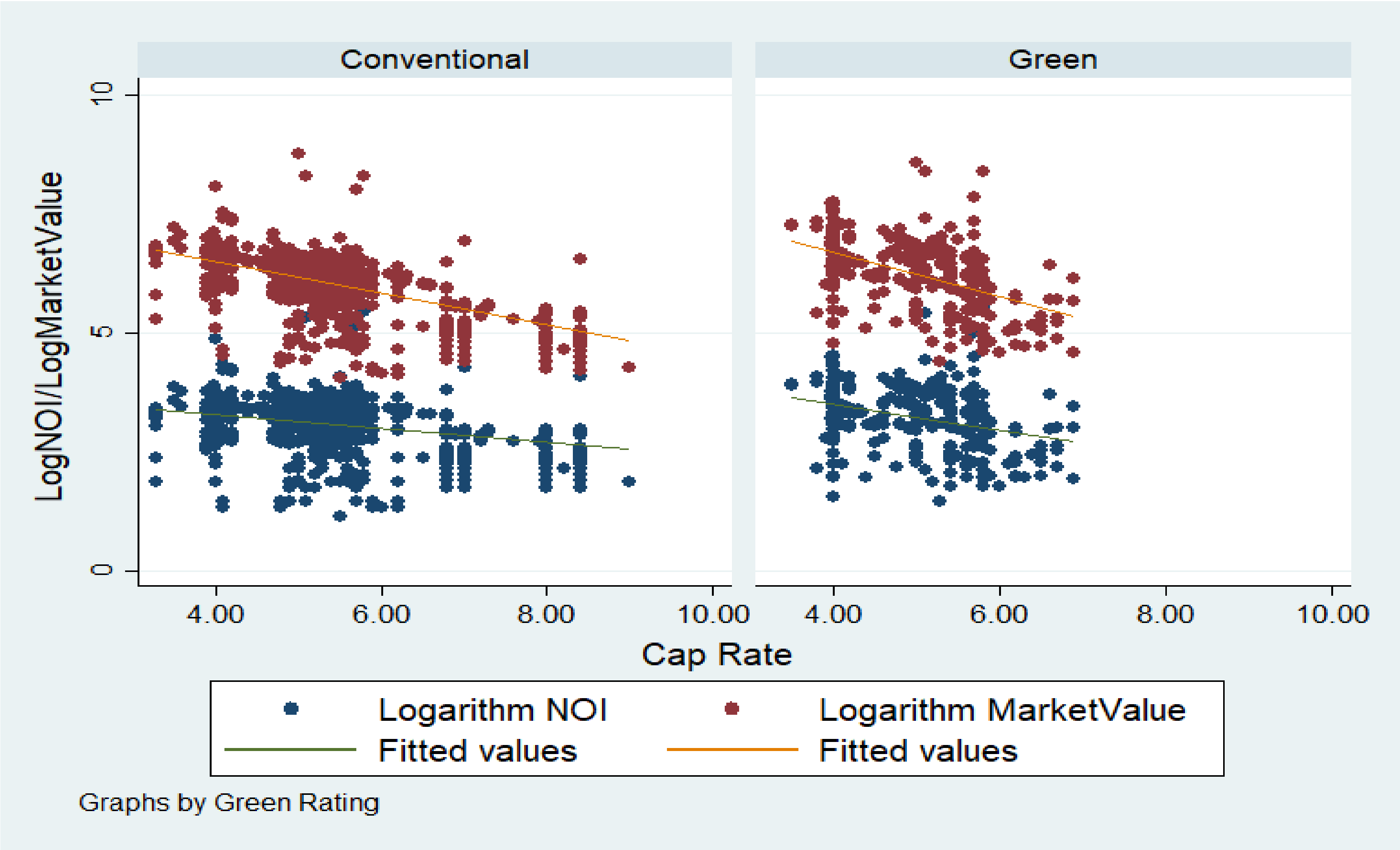

Figure 6: log NOI, log MV Distribution and Fitted Values across all MSAs for Green and Conventional Office Properties

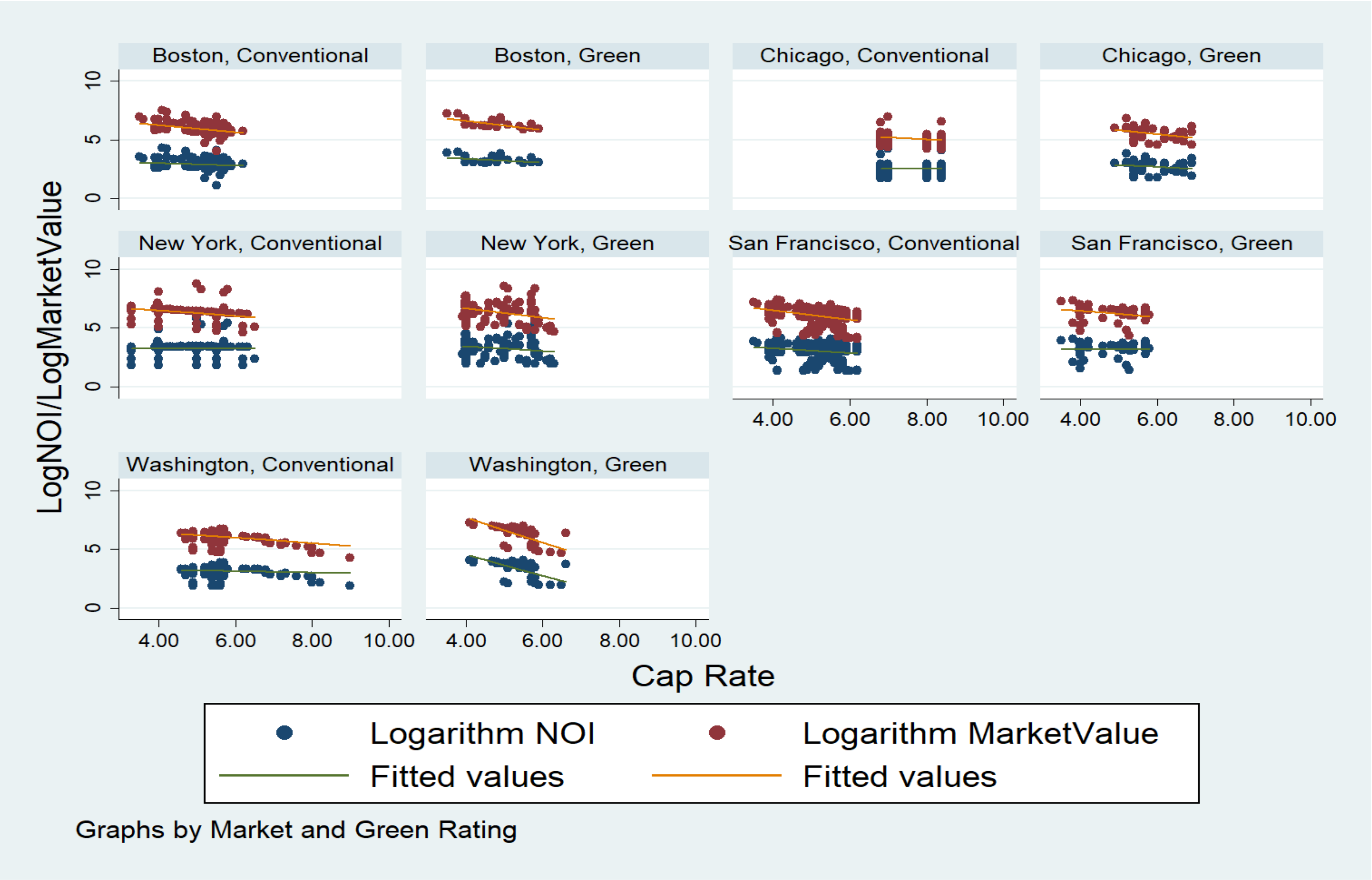

Figure 7: log NOI and log MV Distribution and Fitted Values in Five MSA for Green and Conventional Office

5.2.4 Sensitivity Analysis

5.2.4.1 Propensity Score Matching (PSM[72])

While hedonic regression analysis is the predominant method for capturing pricing premiums, it might be subject to some methodological subjective bias. One limitation of this approach is that often building characteristics of the treatment (certified) and control (conventional) groups differ systematically with respect to characteristics that have direct impact on prices and are entered as independent variables in the hedonic model. If this happens, the hedonic model fails to accurately attribute the value differentials to contributing factors and the model is said to be subject to omitted variable bias. This problem may arise due to unmeasured common features of certified buildings (i.e. micro locational characteristics, certification levels or specific credit category scores). Careful selection of buildings in the control sample that are sufficiently comparable to the treatment sample, in addition to employing PSM techniques ensures that the likelihood of this unwanted bias in the analysis is minimized.

I went the extra mile to estimate the premium for green buildings by ensuring that only the most 'comparable' certified and non-certified properties are placed in each cluster. To achieve highest level of comparability, I employ propensity score matching (PSM) techniques estimated separately by each MSA. PSM aims to select subgroups of certified and non-certified buildings which have a similar covariate distribution. The advantage of PSM is that certified and non-certified buildings are matched on the basis of a single

[72] This method is employed by using 'teffects psmatch' command in Stata package. This method estimates treatment effects from observational data by propensity-score matching. PSM imputes the missing potential outcome for each subject by using an average of the outcomes of similar subjects that receive the other treatment level.

propensity score, which is the probability of receiving certification based on the observed building characteristics, instead of matching on all building characteristics individually. I find that nearest neighbor matching (NN) with the nearest two neighbors best fits my sample in minimizing the differences in covariate means between both treatment and control groups. In this specification, each building is matched to the two buildings with the closest propensity scores. The results of these comparisons, are consistent with the regression results based on larger samples reported in Tables 15 and 16 in previous sections. This further provides strong support to the accuracy of the findings of my regression analyses.

5.2.4.2 Post Regression Diagnostic Tests

The quality of hedonic models can be determined by how well they predict the dependent variable, the linearity of the model and the behavior of the residuals. Without verifying that data have met the assumptions underlying OLS regression, the regression results may be misleading. To check on how well the data meet the underlying assumptions of OLS regression analysis, I employ the following post regression diagnostic tests:

1. Linearity test ensures that the relationship between dependent and independent variables is linear. Figure 8 shows the relationship between log NOI (Y-axis) and predicted/fitted value (Y-hat) of log NOI (X-axis). A 45-degree pattern in data shows that the model does a good job in predicting log NOI[73].

[73] Linearity test for log MV shows similar patterns indicating that MV hedonic model too provide decent predictive power to measure log MV.

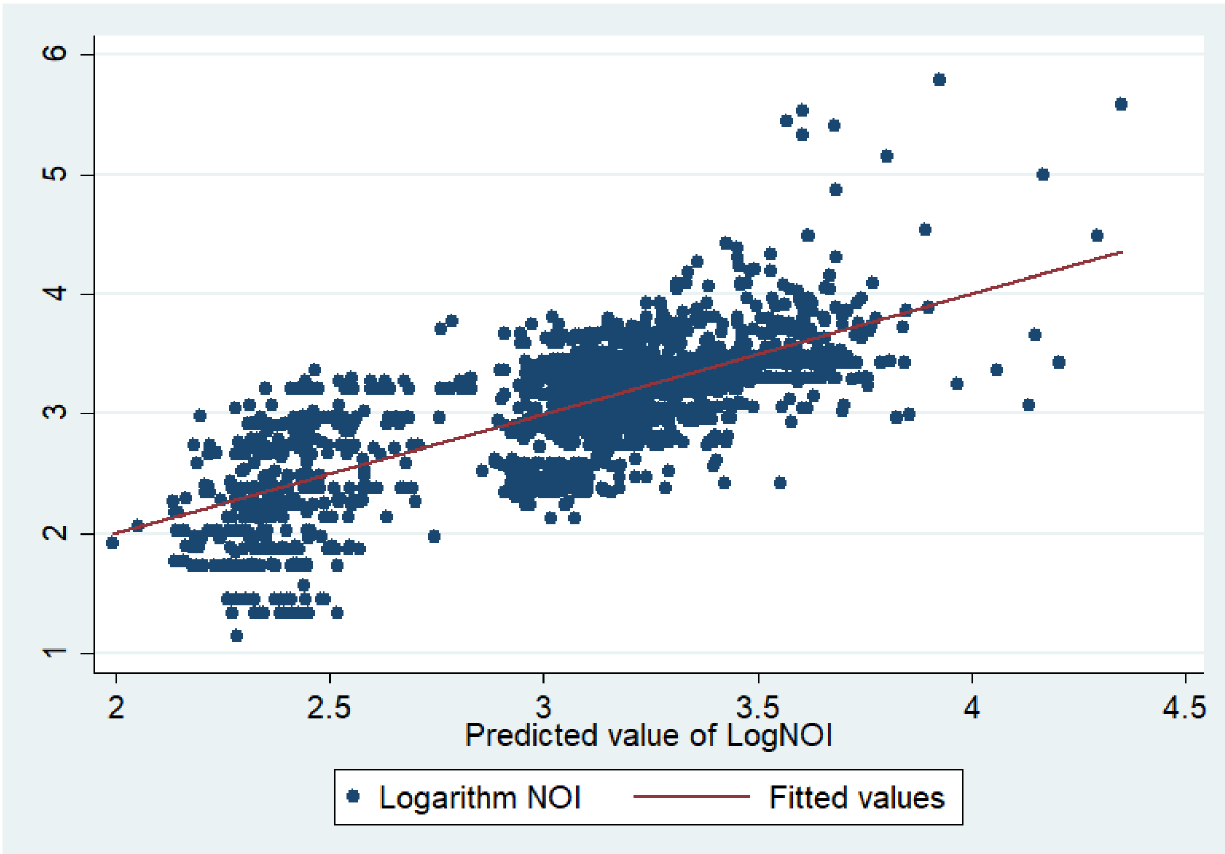

Figure 8: Linearity test-Relationship Between log NOI and Fitted Value

2. Normality test ensures normal distributions of variables and residuals. Some researchers believe that linear regression requires that the dependent and independent variables be normally distributed. Having concluded that dependent variables are not normally distributed, I use log transformed[74] variables to achieve normality in dependent variables[75]. As depicted in figure 9 log NOI presents a much more normal distribution compare to NOI.

[74] One approach to dealing with violations of the normality assumption behind the t-test is to conduct transformations of the data. The goal of the transformation is to mathematically manipulate the data so it becomes more normally distributed.

[75] Exact same procedure is done for MV and same level of normality is achieved through log transformation of variable 'Market Value'.

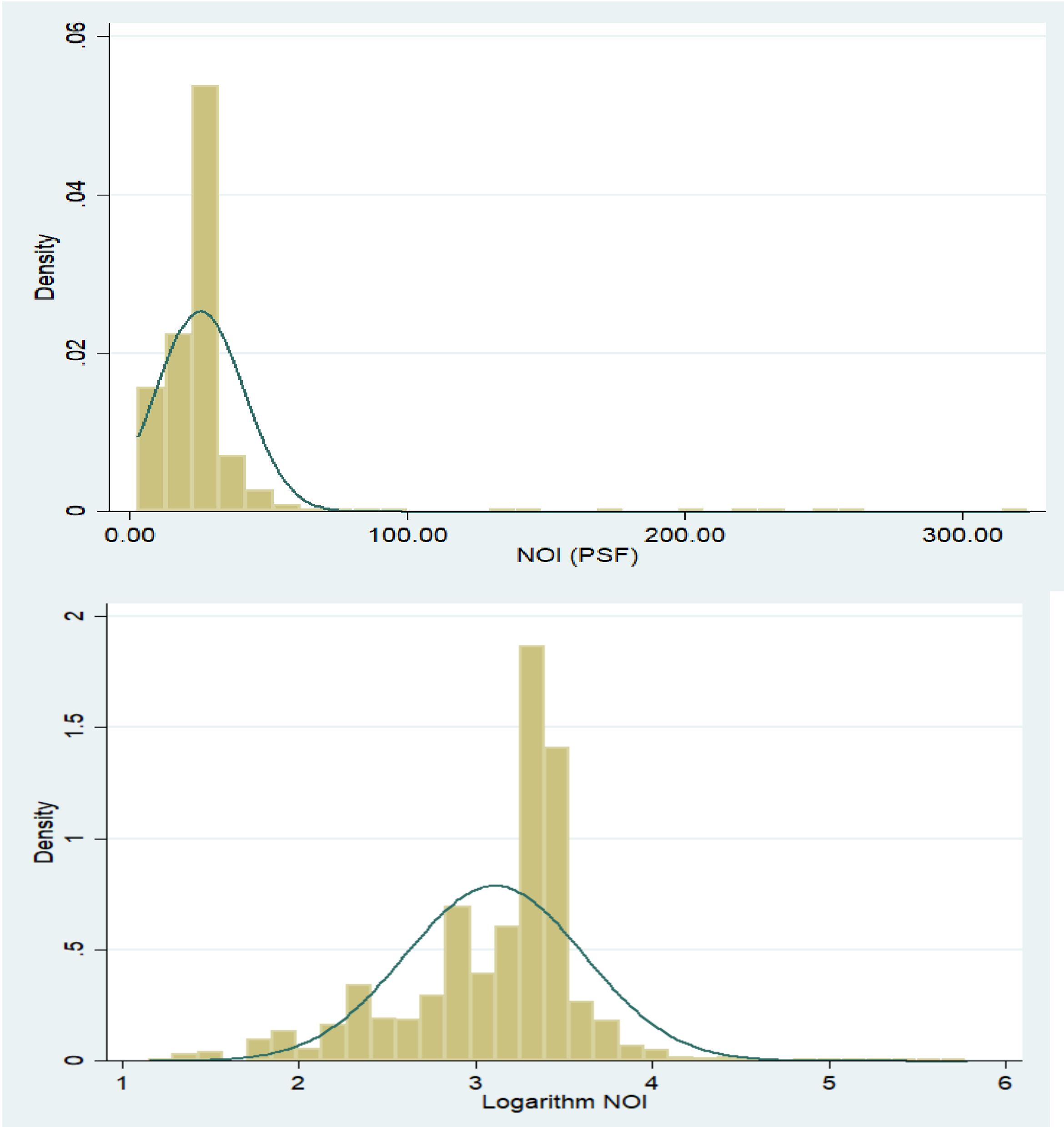

Figure 9: Result of Normality Test for log-transformation of NOI

More importantly, normality test is also employed to ensure that error term is normally distributed[76]. Figure 10 shows that residuals follow a normal pattern meaning that residuals[77] behavior is normal.

[76] Kernel density estimate is arrived at using ‘kdensity r, normal’ command in Stata package.
[77] The difference between observed values (Y) and the predicted values (Y-hat).

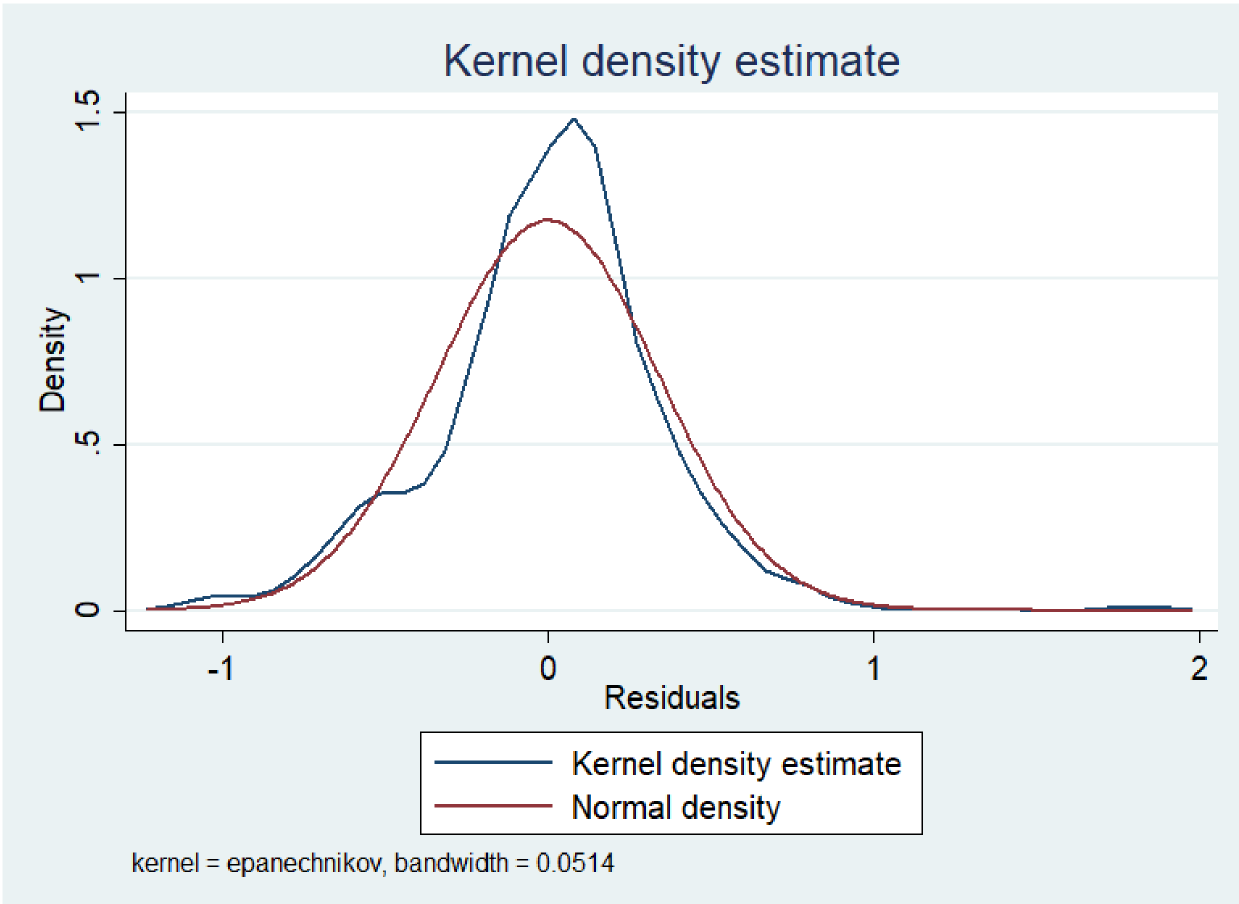

Figure 10: Kernel Density Estimate to Test Normal Distribution of Residuals

3. Homoscedasticity test is used to ensure that the variance in the residuals is indeed homoskedastic[78]. If the model is well-fitted, there should be no pattern to the residuals plotted against the fitted values. In order to test for homoscedasticity[79], I plot residuals vs. predicted values and confirm that no particular pattern is observed. This verifies the assumption that the variance in the residuals is indeed homoskedastic.

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[78] The error term [e] is homoskedastic if the variance of the conditional distribution of [ei] is constant for i=1…n, otherwise, the error term is heteroskedastic.
[79] This test is done using 'rvfplot' command in Stata.

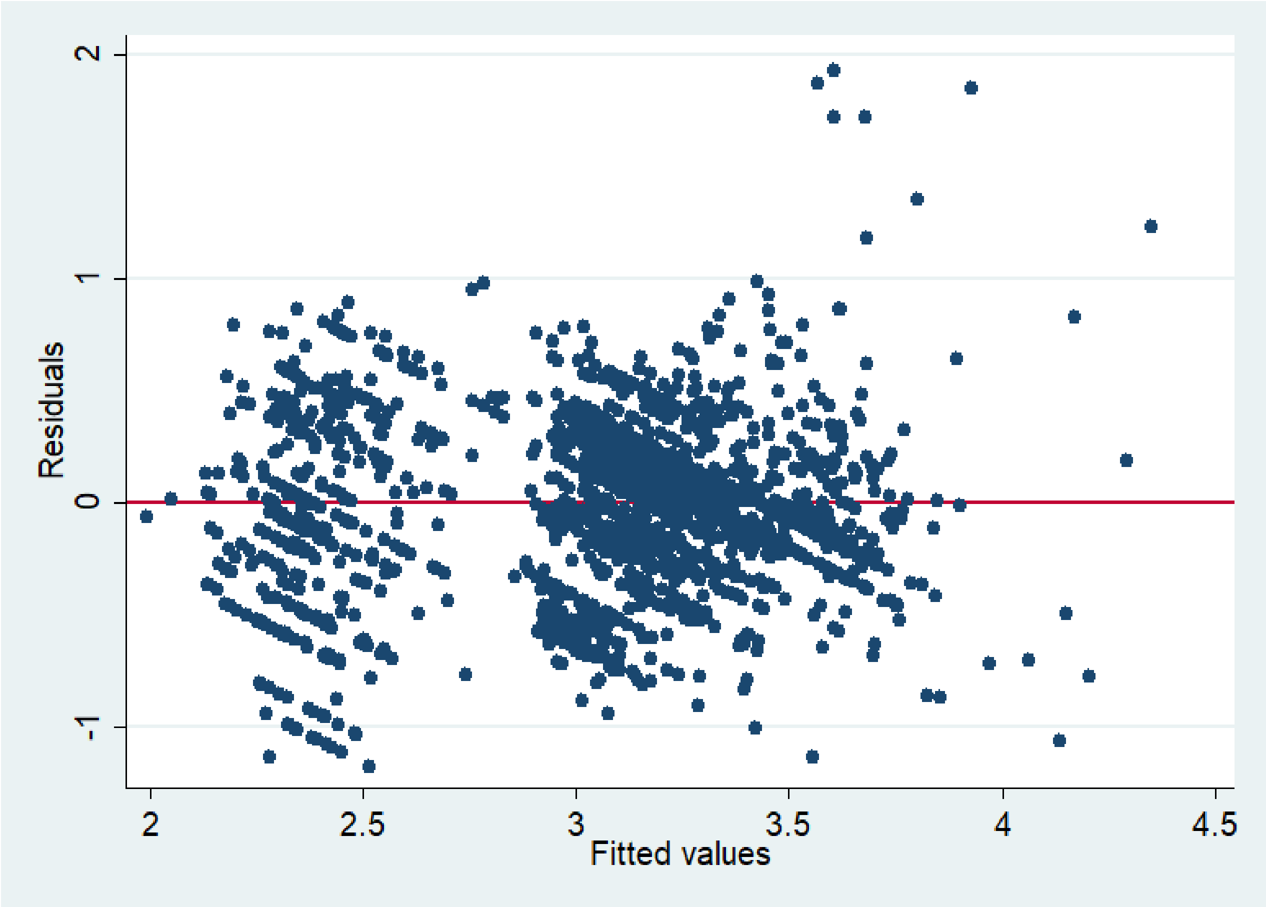

Figure11: Homoscedasticity Test for Error Term

4. Model Specification test ensures that no relevant variables are omitted from the model. I employed the omitted-variable test[80] to ensure that the error term and independent variables are not correlated. As a result, I concluded that the hedonic models do not need more variables to accurately predict dependent variables.

5. Moreover, to improve the validity of the hedonic model and regression analyses, the model is also controlled for multicollinearity, and presence of outliers none of which are found to be present in my data analyses.

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[80] This is done using 'ovtest' command in Stata.

CHAPTER 6. CONCLUSION

6.1 Summary & Discussion of Findings

Over the past decade, green buildings have continued to gain sustained momentum on a global scale. In tune with this market transformation, there has been a growing body of empirical evidence on the financial implications of green building certifications. The existing literature tells us that investment in green buildings renders significant economic advantage through value differentiation. However, most of these studies are based on the CoStar database, potentially suffering from systematically biased data. Additionally, for the most part, the focus has been on standard financial metrics such as rents, occupancy rates and sales prices. Using two of the most comprehensive proprietary databases in the U.S., albeit rarely used in the literature, this dissertation seeks to add to the literature and increase scholarly and practical understanding of the implications of LEED and Energy Star green building certifications on two of the most crucial determinants of green building economic performance, namely net operating income (NOI) and market value (MV).

In broad terms this research provides empirical evidence that bolster the case for superior economic performance in green buildings. This dissertation provides the first systematic investigation on the economic performance of green buildings, in the metropolitan statistical areas (MSA) of five major U.S. gateway cities[81], within the context of a dynamic supply and demand framework as measured by *ex post* achieved NOI and MV over the 2005–2015 and 2010-2015 periods, respectively. Using Trepp database, I investigate the impact of green certifications on NOI of real estate office assets tied to a pool of commercial mortgage backed security (CMBS) loans. In addition, I investigate the

[81] Boston, Chicago, New York, San Francisco, and Washington D.C.

impact of green certifications on office buildings' market value through analyzing actual sales transactions from Real Capital Analytics (RCA) database.

In Chapter 1, I provide general background on the subject, lay out the conceptual framework of this study and identify research's question, scope, significance and objectives. Chapter 2 provides a thorough treatment of the literature on green building economics as well as a detailed analysis of the economic drivers of green building value. In Chapter 3, I outline data description and collection procedure. Chapter 3 explains how I match and collect data on treatment and control observations using GBIG, Trepp and RCA data sets and construct 'Trepp NOI' and 'RCA MV' Samples. In Chapter 4, I introduce hedonic empirical models and describe variables employed in this study. The summary statistics and correlation matrices as described in Chapter 5 indicate that these two samples of properties are well matched considering buildings' hedonic and quality characteristics and other control variables which indicates the strength of the comparables. This in turn helps facilitate careful regression analyses of the certification effect with strong and robust estimated equations with predictions that confirms expected signs as inferred, *a priori*, from descriptive statistics and correlation charts.

Using two hedonic models with the natural log of average NOI and MV (per square foot) as dependent variables, I document that, on average and across the full sample of observations in the five gateway cities' real estate office markets, green (i.e. LEED or Energy Star) certifications result in highly significant premiums of 7.9 percent for NOI and 4.6 percent for MV, relative to non-certified buildings in the same submarket. Additionally, the meticulous analysis of the interaction between NOI, MV and cap rates provides substantial evidence for the close relationship between these three determinants of economic performance in real estate assets across five MSA samples from Trepp and RCA. The results clearly indicate that higher MV is a result of higher NOI and/or lower cap rates. This could be explained by the notion that green building is seen as: (1) a sign of better asset (i.e. generates more income); and (2) a sign of safer investment (i.e. attracts a lower risk premium) and therefore trade at higher values and lower cap rates.

The empirical evidence resulting from regression analyses in Chapter 5 lends credence to the supply and demand dynamics and green building value analyses presented in Chapter 2. Last but not least, the results of rigorous sensitivity analysis further provide strong support to the quality of hedonic models, and confirms the accuracy and precision of the findings of regression analyses in this study.

As was previously discussed, the central concern for many investors is whether certified buildings; (1) cost more, (2) operate on lower expenses, (3) generate more revenues and most importantly bring in (4) higher asset values. As investors are as concerned with the value of their investments upon future sale as they are with current cash flow. Taken together, the findings of this study suggest an important direction for a broad range of real estate players to embark on a journey to a more sustainable built environment and move green buildings' agenda forward. Three distinct policy implications put forward by this research as well as three suggestions for future research direction follows.

6.2 Policy Implications

Green building certifications bring greater transparency to the commercial real estate market which is a fragmented, highly competitive marketplace characterized by information asymmetry[82]. By providing meaningful indicators on asset quality and operating efficiency, certifications serve to break down information asymmetry in a noisy and crowded marketplace. Green building certifications not only disclose information about the uncertain performance of a building but also communicate characteristics about the building owner and occupier as well that are independent of the building performance characteristics.

Within the real estate asset market, green buildings are consistently ranked the most appealing real estate investment vehicles among institutional investors. Through investment in green buildings, successful companies not only diversify their portfolios, but also differentiate their real estate assets within a larger crowded marketplace. With respect to the real estate space market, corporate tenants have also started to differentiate green buildings and demand more energy efficient and sustainability features in spaces they occupy to increase their economic output and enhance their public image. The findings of this study clearly indicate that through the lens of supply and demand, investment in green building could be perceived as a golden opportunity that creates significant competitive advantage for companies that own or lease green office space.

From this discussion it can be further observed that the real estate market as a whole is shifting toward certified buildings. In addition to an upward shift in demand, the prospect of rising energy costs as well as stricter sustainability-related regulatory mandates and more prevalent government incentives will only accelerate this shift. This trend is expected to spur more development and bring about an overall growth in supply which leads to an

[82] Information Asymmetry is a situation that favors the more knowledgeable party in a transaction. The real estate market is particularly characterized by information imbalances especially when the assets being traded are of uncertain quality or characteristics.

increased level of market penetration of green buildings. The natural consequence of this market transformation will be redefinition of what constitutes Class A office properties that generate significantly higher income and market value.

The findings of this dissertation provide clear evidence that green office buildings in the MSA of five gateway cities demonstrate superior income and value generating ability in the space and asset markets. The findings are particularly important and informative for real estate developers. As discussed in Chapter 2, the general perception of developers and investors seems to be that switching to more efficient, green construction is more costly, especially when it involves refurbishment of existing buildings. The results of this research suggest that the income and value premiums for green buildings is well above their marginal cost of design and construction. This means that as long as any added upfront cost of building to achieve green certification do not exhaust income and value premiums, developers may be able to recoup the initial upfront cost of construction and still make profits.

It should be noted that although findings indicate that there is currently a measurable premium for developers and investors who take their green buildings to market, the future outcomes are contingent upon real estate market dynamics. By analyzing the interaction of supply and demand, within the context of real estate asset and space markets, the study shows that the growth in green building supply has an economically significant impact on commercial real estate in general and on certified real estate office assets in particular. I show that this impact is twofold. First, the diffusion and expansion of green building market has an important positive gentrification effect on the stock of non-certified properties which can drastically add value to an entire submarket within each metropolitan area. Secondly, with the growing market demand for certified buildings from tenants, more buildings will need to compete on energy efficiency and sustainability metrics, where premiums for green building will become ‘brown discounts’ for non-green buildings.

As green building supply growth exceeds the market equilibrium point, in the long-run and due to the decreasing marginal effect of green building certifications, it is expected that demand for green buildings declines. Eventually, when green building become the norm and a large share of the office stock is certified, the part of the income premium associated with value differentiation and public image benefits will likely diminish. This is a clear indication of the importance of timing in making investment decisions with respect to involvement in green building construction and/or retrofitting projects. Companies that fail to act quickly and follow the shift in market toward sustainability will eventually face a competitive disadvantage from higher operating costs, lower income, faster depreciation, and accelerated obsolescence.

Return on investment is the basis on which lenders assess the feasibility and risk level of investment in real estate assets. Thus, accurately assessing green building market value premium is essential in order for green buildings to attract mainstream investment capital. The economic benefits uncovered through the regression analysis in this study carry significant income and value implications which are relevant and instructive for both investment and appraisal communities alike. The findings of this dissertation offers insight into the potential of greater economic performance and higher return on investment allowing appraisers to better assess green value. This is particularly important because significant investment in building certifications will not be implemented unless there is convincing evidence of value premiums for investors. Consequently, assessing this added value is essential for considerable growth and expansion of green buildings.

I believe that important decisions regarding investment in green buildings will be based on a combination of accurate quantitative analysis informed by the qualitative factors and judgment of investors, underwriters, lender and appraisers. The findings of this study, therefore, lays a strong quantitative foundation for the investment community to rely upon when making decisions with respect to the green buildings investment and economic performance. With respect to higher NOI and higher MV, the findings of this study predict that investors in green buildings could anticipate higher income growth, and faster appreciation of office assets. Moreover, the results indicate that green office properties are less exposed to risk from projected rise in energy expenses, real estate market downturn, and strict government regulations. Consequently, investors could view green office properties as safer vehicles of investment to diversify their portfolios. In an efficient market, it is expected that these findings will increasingly be reflected in choices and underwriting decisions made by real estate investors and lenders, further reinforcing the effect of building quality and green certifications on green building market value. Consequently, I expect that the positive results of this study, create further support for green building certifications through better valuation, increased investor attention and enhanced access to capital both debt and equity.

With that being said, there are a number of caveats attached to the interpretation of findings of this study. In doing empirical analysis of value differentials, the controls for inherent heterogeneity between certified and non-certified buildings are bound to be imperfect even when applying the most diligent sample selection process and the most comprehensive set of variables in the hedonic model. For instance, investment in green building certification is only one element of the variety of methods companies use to differentiates their real estate portfolio from their competitors. To control for all other marketing facets companies employ to positioning an asset in the upper segment of the market is virtually impossible in the framework of a hedonic model. Moreover, although the findings of this work are in line with the findings of the majority of studies on price premium of certified buildings, like many others, this empirical study provide a cross-sectional snapshot of value differentials of a niche market (i.e. MSA of five U.S. gateway cities) with relatively small sample sizes and in a specific time period. It is expected that value differentials for certified buildings should vary over time and between buildings. This calls for further investigation to confirm these findings and substantiate more empirical evidence regarding superior economic performance of green buildings as their market share increases over the next decade.

6.3 Direction of Future Research

The work exhibited in this dissertations presents three clear paths for future research. First, the documented positive marginal economic output of certified buildings, achieved through higher NOI and higher MV, in this study may simply reflect their higher construction costs. This is because demand side responds to changes in supply. Although anecdotal evidence hold that green buildings require no or miniscule cost premiums, to date, there is limited systematic evidence reporting on the marginal construction costs of certified real estate in the U.S. commercial real estate sector. Furthermore, the transaction costs associated with certification, consulting, design fees, contingencies and development are largely unavailable (Chegut et al., 2015). Unfortunately, current transaction cost data are insufficient for meaningful statistical inferences. Thus, future research incorporating construction and redevelopment cost may provide a better understanding of the economic performance and return on investment related to investments in green building. Also, it will be interesting to see if there is a relationship between the level of certification in new construction projects and the construction costs and value determinants of green buildings[83].

Second, although the estimated premiums in NOI and MV are significantly higher for certified buildings than for the most comparable non-certified buildings, the statistical analysis in this research does not identify the definitive source of this premium. The regression results also do not provide evidence for causality, they only provide enough evidence to suggest that there is a relationship between certification and higher economic performance. The mere existence of this relationship, however, calls for further empirical research to investigate and identify the source of premiums in income and market value in certified buildings. This dissertation bundles Energy Star and LEED buildings together and label them as 'green'. In reality though, the NOI and MV premiums associated with certifications on any building represents the joint effects of the energy and resource efficiency of the building together with other unmeasured, but presumably important, attributes of the building. Given the magnitude and significance of these documented premiums, it seems plausible that additional factors are adding value to green buildings beyond the simple higher rents and savings in energy expenses. Further research is required to investigate and analyze the impact of intangible benefits associated with green building

[83] Due to the limited number of certified buildings sales transaction, it is currently not possible to identify and establish a relationship between the achieved level of LEED certification and the percentage of property value increase.

certification (i.e. public image benefits, higher productivity or lower investment risk) on the income and value premiums in green buildings. As more evidence of superior economic performance of green building emerges, capital providers will become more optimistic about the potential of higher return on their investment.

Third, in Chapter 5, I provide an analysis on office properties' lease structure and concluded that NOI and OpEx are higher in buildings let on a gross lease basis. Also, I discuss that the proportion of gross leases appears to be significantly higher compared to net leases in the Trepp NOI sample. More thorough investigation is required to elaborate on the impact of lease structures on net operating income and operating expenses. In this regard, it would be interesting to analyze how higher NOI and OpEx in green buildings are reflected in rents achieved by properties let on NNN and gross leases. Moreover, summary statistics and correlation matrices in Chapter 5 provide evidence of significantly higher OpEx and slightly lower occupancy rates in green buildings. Further empirical analysis of the implications of green building certifications on total OpEx and occupancy levels can provide more evidence to make a stronger business case for green buildings. This will in turn shed some light on the actual sources of higher NOI and MV uncovered in this study. Last but not least, further regression analysis to isolate the impact of different type of certification category as identified in this dissertation (i.e. LEED, Energy Star and Dual) and analyze and investigate their implications on NOI and MV could provide another dimension to the findings uncovered through this research.

APPENDIX A
Green Building Policies in Five U.S. Gateway Cities

1. Boston

1.1 Energy benchmarking ordinance

In April 2013, the city council adopted the "Building Energy Reporting and Disclosure Ordinance" that requires all commercial buildings over 35,000 Sq. Ft. to benchmark their energy and water use and report the data to the city annually. The policy includes mechanisms for enforcement and penalties in cases of non-compliance.

1.2 Green building mandate: Municipal Zoning Code Volume I Article 37

On January 10, 2007, the City of Boston amended Article 37 of the Municipal Zoning Code to require that all large-scale projects meet LEED Certified standards. Such projects may additionally obtain a maximum of four Boston Green Building Credits• , one from each of the defined categories: Modern Grid, Historic Preservation, Groundwater Recharge, and Modern Mobility. These Green Building Credits will be included in the calculation toward achieving LEED Certification. Applicants must submit a completed LEED scorecard, including any Boston Green Credits, to the Boston Redevelopment Authority for review.

2. Chicago

2.1 Energy benchmarking ordinance

The "Chicago Energy Use Benchmarking Ordinance" requires commercial and residential buildings greater than 50,000 Sq. Ft. to annually benchmark, verify the data, and make the information transparent to the city and public. This ordinance was adopted in September 2013, implemented shortly thereafter, and the reporting schedule began in June 2014. Non-compliance holds a daily fine.

2.2 Green building mandate: Sustainable Development Policy

In June 2004, the City of Chicago passed a resolution requiring all new city-funded construction and major renovation projects to earn LEED certification. The policy has been updated in the following years, and became the Chicago Sustainable Development Policy. In 2016, the policy was updated again to allow developers to choose from a menu of strategies that can be tailored to fit the project's needs. New construction projects are required to achieve 100 points and renovations of existing buildings are required to reach 25 or 50 points depending on the scale of the renovation. The updated policy provides two compliance paths. One path does not require the building to be certified through a listed building certification program. Projects choosing this path must meet the points required through the strategies listed in the menu. The second path is for projects that are choosing to achieve building certification. Points are automatically given to these projects depending on the type of building certification being achieved and also the level of certification in some instances. Additional points are required except for projects that are being certified under the Living Building Challenge program.

3. New York

3.1 Energy benchmarking ordinance

"NYC Law 84" requires annual benchmarking and public disclosure for commercial buildings larger than 50,000 Sq. Ft., and groups of smaller buildings on a single lot that together are larger than 100,000 Sq. Ft. This policy was enacted December 2009 and was implemented in May 2010. In October 2016, the New York City Council voted to amend the law to include mid-size buildings that are larger than 25,000 Sq. Ft.

Reporting of energy and water use to the City will begin in 2018. Failure to comply with the law results in a fine.

3.2 Green building mandate: NYC green building policy

On March 28, 2016, New York City enacted Local Law 2016/032. The law amends the city's green building policy, providing that each capital project with an estimated construction cost of $2 million or involving the construction of a new building, and addition to an existing building, or the substantial reconstruction of an existing building shall be designed and constructed to comply with green building standards not less stringent than the standards prescribed for buildings designed in accordance with the LEED Green Building Rating System to achieve LEED Gold of higher rating. Certain building types will only be required to achieve certification at the Certified level or higher.

4. San Francisco

4.1 Energy benchmarking ordinance:

Chapter 20 of the "San Francisco Environment Code" requires audits and public transparency of benchmarks for all commercial buildings over 10,000 Sq. Ft. This chapter was approved by the city council in February 2011 and its implementation was phased in over three years. Non-compliance may result in a fine.

4.2 Green building mandate: Green Building Code

On November 22, 2016, the Board of Supervisors of the City and the County of San Francisco adopted amendments to the city's Green Building Code. The updated law requires commercial buildings over 25,000 square feet to achieve Gold certification under the appropriate version of LEED v4, v4 Silver or Green Point Rated certification for any new residential development, and for any new commercial or residential development of ten floors or more to have at least 15% of the roof area have photovoltaic panels, solar thermal technology, or green roof features. Additionally, starting January 1, 2018, all new buildings, regardless of size, will be required to provide electric-car charging stations for a minimum of 20% of parking spaces on premises.

5. District of Columbia

5.1 Energy benchmarking ordinance

Washington, D.C.: "The Clean and Affordable Energy Act" requires commercial buildings over 50,000 Sq. Ft. to benchmark and publicly disclose energy usage data annually. This policy was adopted July 2008, and implementation began in 2010. Non-compliance results in a fine.

5.2 Green building mandate: Green Building Act of 2006

The Green Building Act of 2006 requires that all non-residential District public buildings meet the U.S. Green Building Council's LEED certification standards for environmental performance at the "Silver" level or higher. District owned or financed residential projects 10,000 square feet or larger must meet or exceed the Green Communities certification standard. Since January 2012, all new private development projects 50,000 square feet or larger are now required to meet LEED certification at the "Certified" level or higher.

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