Do Green Buildings Capture Higher Market-Values and Prices? A Case-Study of LEED and BOMA-BEST Properties

by

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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Environmental Studies
in
Environment and Resource Studies

Waterloo, Ontario, Canada, 2014

Author Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revision, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

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Abstract

It is becoming increasingly clear that as the pressures of climate change increase around the world, all nations must strive to lower their carbon footprint through conservation. In our society, the buildings sectors impose heavy environmental burdens going beyond green house gas emissions. As such, it is becoming increasingly urgent to promote 'green' buildings and infrastructure. At the same time, innovations in technology must be based upon sound socio-economic and technological evidence. Fortunately, green certified buildings have been on the rise over the past decade. However, they continue to face numerous challenges, including uncertainty with respect to how well they perform from a socio-economic and technical standpoint. If this growth trend is to be continued and improved upon, then evidence must be collected as to the benefits they bring about, and the level of support they enjoy in the market. As such, now is an opportune time to examine how well they perform in the real estate market. This thesis aims to shed light on the economic performance of green buildings by evaluating whether LEED for Homes and BOMA-BEST properties capture higher market-valuations, prices, and lower vacancy-rates. Our literature review revealed that these types of research questions have not been addressed to a great deal in the context of Canadian academic research and writing.

The analysis was conducted using multi-variable regression models, and paired-analysis techniques borrowed from the appraisal sciences. Also, commercial vacancy rates were compared through the use of chi-square tests and tests of group means. Our analysis did not lead to conclusive evidence that there exists a 'green' premium in the real-estate market with respect to market valuations. Firstly, the certification variables did not show themselves to be positive and statistically-significant. We argue that this may largely be due to appraisal methods that currently do not incorporate sustainability factors. The paired-analysis for residential properties yielded some evidence of a price premium; however, greater amount of research is required to confirm this. Furthermore, while the vacancy-rates of green commercial buildings were, on the whole, lower than their non-green counterparts, the differences were not statistically-significant. Given these results, we propose a set of policies for industry, academia, the appraisal community, and governments.

Acknowledgements

I would like to thank my supervisor, Ian Rowlands, for his guidance and support over the course of the last two years. Your encouragement and high standards have allowed me to produce a study that I am proud of. I have gained everything from the program that I had wanted to upon starting my degree, and a lot of this is due to your friendship and professionalism. I would also like to thank Professor Olaf Weber for his support and ideas during the completion of the thesis. Your help and advice on the technical aspects of this thesis is highly appreciated, and has helped make this a better study. Also, my thanks go out to Professor Markus Moos for his insight and advice during the defence, which I have incorporated into this final product.

Furthermore, this study was completed with support from the NSERC Smart Net-Zero Energy Buildings Strategic Research Network (SNEBRN), under the Strategic Research Networks programme of the Natural Sciences and Engineering Research Council of Canada (NSERC).

I would also like to thank the ever-present love and support of my family and friends. All my achievements and progress in life have been made possible through your help and encouragement, including the past two years of graduate studies. Lastly, I would like to thank my lovely Erica for the love and friendship you provide me every day. I am grateful for the life we have built together and this would not have been possible without you. You are my greatest champion.

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1.0 - Introduction

In an era of fiscal restraint, public authorities all over the world today must balance the needs of the economy while striving to protect the environment at the same time. In some cases, the interests of the environment and the economy coincide, while in other cases they may collide. However, the challenges associated with climate change continue to rise adding to the need for greater urgency. Our efforts to mitigate or adapt to these effects must also be conducted in a cost-effective manner increasing the complexity of the task at hand.

One of the ways we may be able to lessen our carbon footprint while lowering both public infrastructure and business operating costs is through the promotion of green building infrastructure. Businesses in our communities may be able to benefit from green buildings through lower operating costs (e.g., lower utility bills) in addition to a host of other commercial benefits (Lutzkendorf and Lorenz, 2013). Society may benefit from the lower carbon footprint green buildings could help to promote through lower energy consumption, and other associated environmental benefits (UBC, 2010).

Although building codes around the country and around the world are strengthened periodically, there exists the possibility of accelerating the pace of building resource efficiency even further. Also, building codes generally strive to provide a 'base-line' and the role of the environment or resource-efficiency may be one amongst a number of other socio-economic and safety considerations and priorities (CEC, 2013). Fortunately, as we will demonstrate in this paper, the process has already begun and the task at hand for the academic, business, and policy communities is to ensure that we can continue or even accelerate the progress on green building development.

However, there are some key socio-economic and technical barriers that continue to hold back progress, and it is essential that the proponents of green buildings adequately address these concerns. One of the barriers going forward is uncertainty with respect to how well green buildings "perform" in the real-estate market. That is, whether real-estate clients place a higher

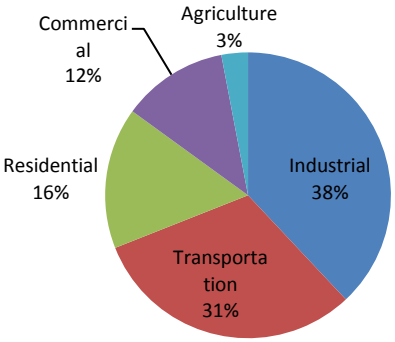
premium on "green" features and are willing to pay extra for them is unclear, and the academic community in Canada has not produced the required analysis on this question. This study will attempt to shed some light on aspects of this broader question using rigorous quantitative methods. Specifically, we primarily investigated whether green buildings (those which have received LEED or BOMA BEST designations)[1] capture higher market-valuations (assessed by appraisal agencies) or sale prices. We carried out this analysis using regression models where the dependent variable is the assessed market-value of each property as of a particular date, and the explanatory variables are some of the key 'hedonic' characteristics associated with the property. This analysis was carried out for both the residential and commercial real-estate sectors in the provinces of British Columbia, Alberta, Ontario, and Quebec.

In addition to this analysis, borrowing from some of the techniques utilised in the appraisal sciences, we conducted a 'paired' comparison of three green (LEED certified) homes in the province of Ontario to investigate whether green residential properties capture higher selling prices. Lastly, a secondary analysis of vacancy rates in the commercial sector (in the cities of Calgary, Toronto, and Montreal) was also carried out to test whether green commercial properties have lower vacancy rates.

1.1 - The Role of Green Buildings in Energy-Efficiency and Sustainability

The environmental impact of both residential and commercial buildings is substantial. As can be seen in the Figure-1.1, together the real-estate buildings sectors consumed 28% of secondary energy as of 2010. The only other sectors which outrank real-estate in terms of energy-usage are industrial facilities (38%), and transportation (31%) (Natural Resources Canada, 2013).

Figure. 1.1: Secondary Energy-use, 2010

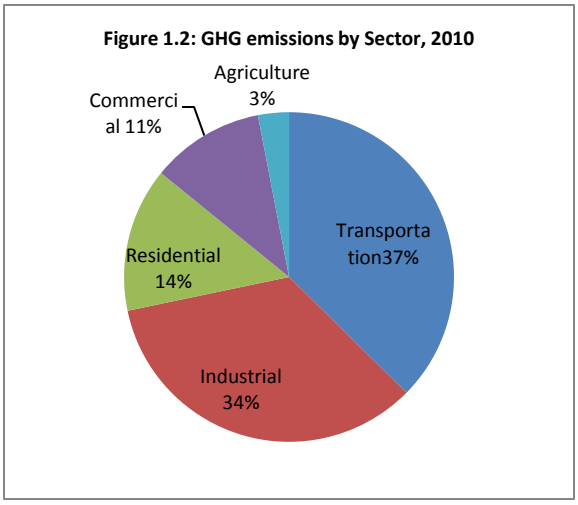


Source: Natural Resources Canada, 2013.

Furthermore, when we break down greenhouse gas emissions by sector (Fig-1.2), a similar picture emerges again. The residential and commercial buildings sectors are responsible for

[1] LEED =Leadership in Energy and Environmental Design, BOMA = Building Owners and Managers Association.

approximately 24% of greenhouse gas emissions nationally; the residential sector leads to 14% while the commercial sector stands at 11% (Natural Resources Canada, 2013).



Source: Natural Resources Canada, 2013.

The real-estate sectors have, for the most part, grown in terms of their energy and greenhouse gas impact over the past two decades. Table-1.1 below shows that, in terms of secondary energy-use growth, the commercial sector has grown substantially by 22% over the 1990-2010 year period, while the residential sector has grown at a much slower pace of 6%. In terms of GHG emissions growth, the commercial sector has increased its output of emissions by 15%, while the residential sector has decreased its emissions by 0.5%, due to efficiencies. Therefore, on the whole, secondary-energy use and greenhouse gas emissions have increased in the buildings sectors.

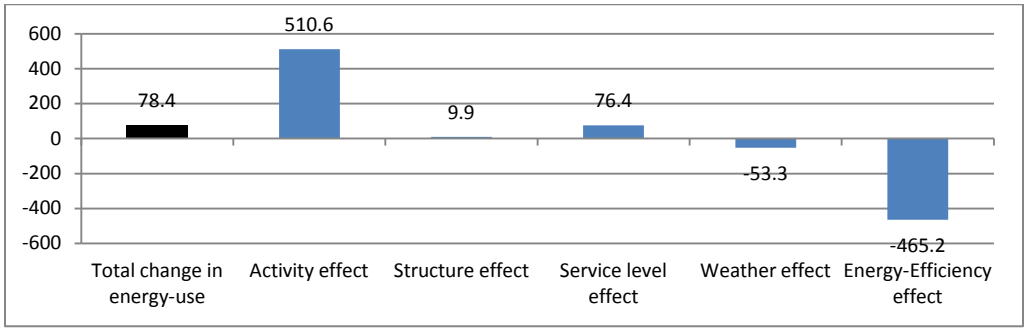
Table 1.1 : Total Secondary Energy-use Growth and Total GHG emissions Growth

Total Secondary Energy-Use growth	1990-2010	Total GHG emissions growth	1990-2010
Residential	6%	Residential	-0.5%
Commercial	22%	Commercial	15%
Industrial	19%	Industrial	20%
Transportation	38%	Transportation	38%
Agriculture	23%	Agriculture	24%

Source: Natural Resources Canada, 2013.

Considering energy use, the vast majority of the growth in energy use is due to the increase in both residential and commercial floor space. As the two graphs (Fig.-1.3, 1.4) below illustrate, if we break down the growth in secondary energy use in the residential sector, the vast majority of the increase is due to an increase in "activity", that is, an increase in floor area (by 50%) and a 35.2% increase in the number of households (Natural Resources Canada, 2013). Thus, the higher number of households and floor-space led to an increase of 510 peta-joules in residential secondary energy-use, despite an improvement in energy-efficiency which lowered demand by over 465 peta-joules. Therefore, overall, secondary energy-use increased by 78.4 peta-joules over the 1990-2010 period (ibid, 2013).

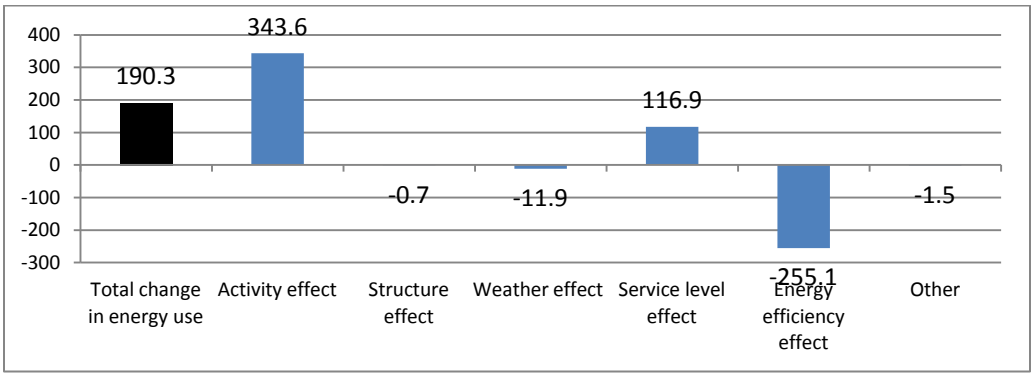
Figure 1.3 Total Change in Energy-Use (Peta-Joules): 1990-2010 (Residential)



Source: Natural Resources Canada, 2013.

Similarly, for the commercial sector, the vast majority of the growth in secondary energyuse was brought about by a 41% increase in floor-space over the twenty years, leading to a 190 peta-joule increase in total energy-use. At the same time, energy efficiency improved and lowered demand by 255 peta-joules (Fig- 1.4) (Natural Resources Canada, 2013).

Figure 1.4 Total change in Energy-Use (Peta-Joules): 1990-2010 (Commercial)



Source: Natural Resources Canada, 2013.

In sum, despite increasing efficiencies, the environmental footprint of the buildings sector has grown over the past two decades due to the increasing number of buildings being constructed across the country.

Water Consumption: the Buildings Sector

Another significant environmental impact of the buildings sectors occurs with respect to water consumption. As can be seen in the pie-charts (Fig-1.5, 1.6) below, 9.5% percent of water consumption occurs at the municipal level. Out of this total, the residential sector consumes

almost two-thirds of water in the municipal context. The commercial sector is second with 19% of municipal water consumption. Therefore, the water consumption footprint of the real-estate sectors is substantial.

Figure 1.5 Canada's Water Consumption , 2006

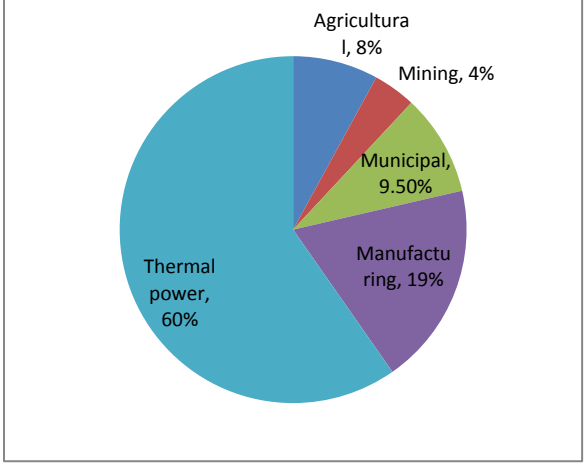
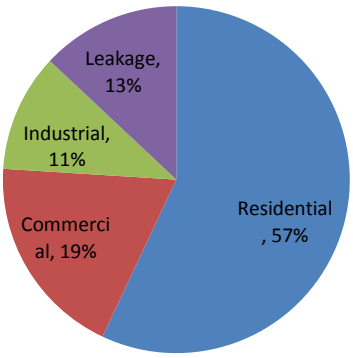


Figure 1.6 Municipal water consumption, 2010



Source: RealPac, 2011.

We have discussed that both the resdiential and commercial sectors impose significant demands on our natural resources. These trends are likely to continue as well. According to the latest forecast by the National Energy Board (Table-1.2), energy-demand in the residential and commercial sectors is predicted to rise annually by 0.7% annually over the 2012-2035 period (National Energy Board, 2013).

Table 1.2 End-use Energy Demand by Sector (% annual growth- 2012-2035), Baseline

Residential	0.7
Commercial	0.7
Industrial	1.4
Transportation	0.8
Total End-Use	1.1

Source: National Energy Board, 2013.

Furthermore, if we consider green house gas emissions, we can see from Table-1.3 below that the buildings sector is forecasted to increase emissions over the 2005 to 2020 period by 11 mega-tonnes. Indeed, it is predicted to be one of the four leading contributors to greenhouse gas emissions growth over the 2005 to 2020 period.

Table 1.3 Change in GHG emissions by economic sector (Mt CO2e)				
	2005	**2011**	**2020**	**2005 to 2020**
Transportation	168	170	176	8
Oil and Gas	162	163	200	38
Electricity	121	90	82	-39
Buildings	84	84	95	11
Emissions Intensive and Trade-exposed industries	87	78	90	3
Agriculture	68	68	69	2
Waste and Others	49	49	50	1

Source: Environment Canada, 2013.

To conclude, we have discussed thus far that buildings (both in the residential and commercial sectors) do impose a substantial environmental burden with respect to the use of both water and energy, and their operations result in significant greenhouse gas emissions. Furthermore, this environmental impact is likely to continue into at least the near-future despite the anticipated improvements in technology and their associated efficiency gains.

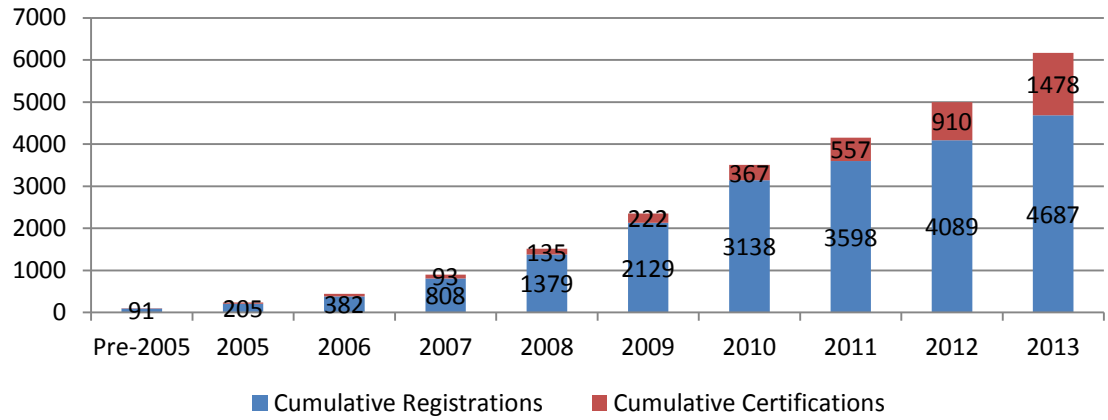
One of the ways the environmental footprint of buildings could be mitigated is through the promotion and further growth of "green" buildings. While there does not exist a strict definition as to what constitutes a green building, both the academic and commercial literatures have produced numerous analyses lending support to both their economic and environmental benefits. For instance, a recent global review by Zuo and Zhao (2014) of green building studies pointed to numerous environmental and non-environmental benefits that are being catalogued by researchers. In their review, some of the main environmental benefits of green buildings are the promotion of urban biodiversity, eco-system protection, reduction of waste (both construction and demolition), and greater energy and water efficiency. Furthermore, they point out other studies that have demonstrated the value of 'intangibles' such as greater thermal comfort, better indoor air-quality, and higher employee productivity.

Lastly, a recent global survey of real-estate professionals by McGraw-Hill Construction (2013) revealed that the top environmental drivers of green building construction are energy and water savings, better air-quality, and lower greenhouse gas emissions.

1.2 - The state of the green building industry

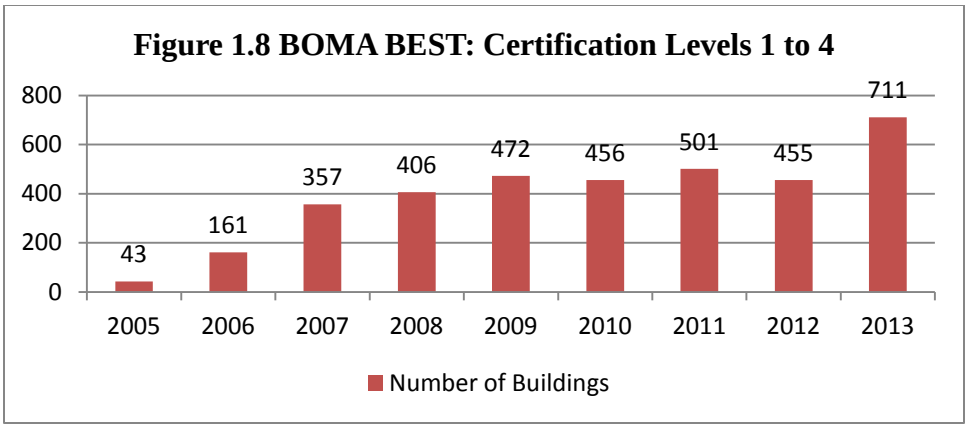
Green building construction has been accelerating in Canada over the past several years. If we consider only the certifications we have studied for this paper we can clearly see impressive growth. Based on the latest available reports, as can be seen in the graph (Fig-1.7) below, since 2005, both the number of LEED cumulative registrations and certifications have been on an impressive upward trend (Canada Green Buildings Council[2], 2014). The same may be seen for the commercial sector, when we examine the number of BOMA BEST certifications awarded since 2005 (for 2012, only Levels 2, 3 and 4 were reported) (BOMA, 2014). Cumulatively, as of 2014, 3562 buildings across Canada since 2005 have either achieved certification or have been recertified (BOMA, 2014).

Figure 1.7 Canada: LEED Projects



Source: Canada Green Buildings Council, 2014.

[2] Canada Green Buildings Council = CaGBC.



Source: Building Operators and Managers Association, 2013.

Indeed, the growth pattern of green buildings in Canada mentioned above is also in line with what real-estate experts and analysts have been reporting over the past several years globally. According to a recent global survey by McGraw-Hill Construction, "fifty-one percent of architects, engineers, contractors, owners and consultants participating in the survey anticipate that more than 60% of their work will be green by 2015, up from 28% of respondents in 2012. And the growth of green is not limited to one geographic region or economic state...it is spreading throughout the global construction market-place" (McGraw-Hill, 2013, Pg. 5).

Furthermore, the same study cited also points out that there are increasingly more financial/economic reasons for 'going green'. We can see from Table-1.4 below that the top reason cited for green construction is due to increasing client-demand for green buildings. Indeed, 41% of respondents in the U.S. cited this as the top factor (37% Australia, and 39% in Europe). We can also see that the promise of lower operating costs and better branding prospects are also key reasons for buying and/or building green (McGraw-Hill Construction, 2013). We will see later in our study (see Discussion) that similar sentiments have been expressed by real-estate professionals in the Canadian context as well.

Table 1.4 Drivers for Green Building Growth			
	United States	**Australia**	**Europe**
Top reason	**Client Demand**	**Market Demand**	**Client Demand**
	41%	37%	39%
Second reason	**Corporate Commitments**	**Client Demand/Lower op cost**	**Market Demand**
	32%	35%	37%
Third reason	**Market Demand/Lower op costs**	**Corporate Commitments**	**Branding/PR**
	30%	31%	34%

Source: McGraw-Hill Construction, 2013.

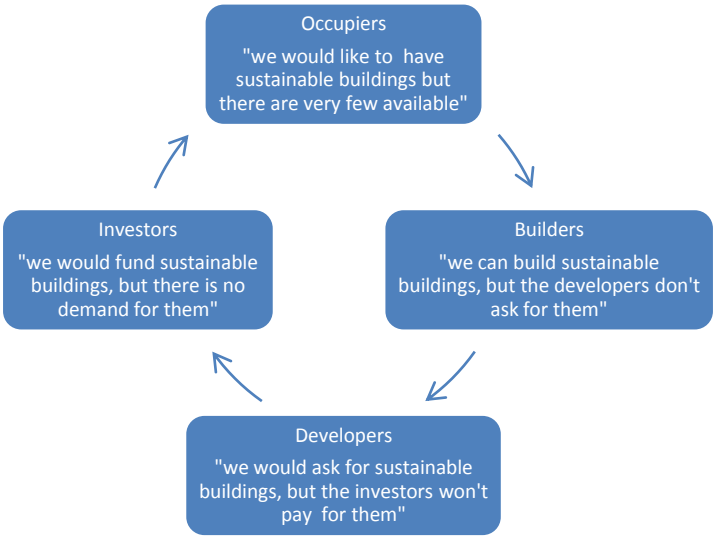
However, while there is reason for optimism, as with all new technologies, there are still various socio-economic and technical barriers that impede the progress of green buildings. We will now proceed to discuss some of these major obstacles.

1.3 - What are the risks and barriers?

A useful framework for understanding the barriers which stand in the way of greater green building diffusion, produced by members of the academic community, is the 'circle of blame'. This concept has been used by various authors (see Warren-Myers, 2012 and Royal Institute of Chartered Surveyors, 2008) to conceptualise and describe the 'major' socio-economic hurdles standing in the way of greater construction, use, and investment in green buildings. As Figure 1.9 below illustrates, in a simplified industry model, the real-estate industry is composed of four major players; the owners/occupiers, the designers/constructors, the developers, and investors. The element of fault or blame arises from the fact that each stakeholder puts forward their own "excuse" for not playing a greater role in the promotion of green buildings.

Thus, the potential occupiers (or clientele) argue that there are not enough green buildings for them to purchase/rent. The builders/designers argue that since developers don't ask for them, there is no incentive for them to design and build these types of structures. Developers, in turn, argue that it doesn't make sense for them to request and plan for green buildings since investors shy away from funding them. Lastly, the investors argue that there currently does not exist sufficient market demand for green buildings, hence the lack of investor response (RICS, 2008).

Figure 1.9 - The Circle of Blame (Source: RICS, 2008)



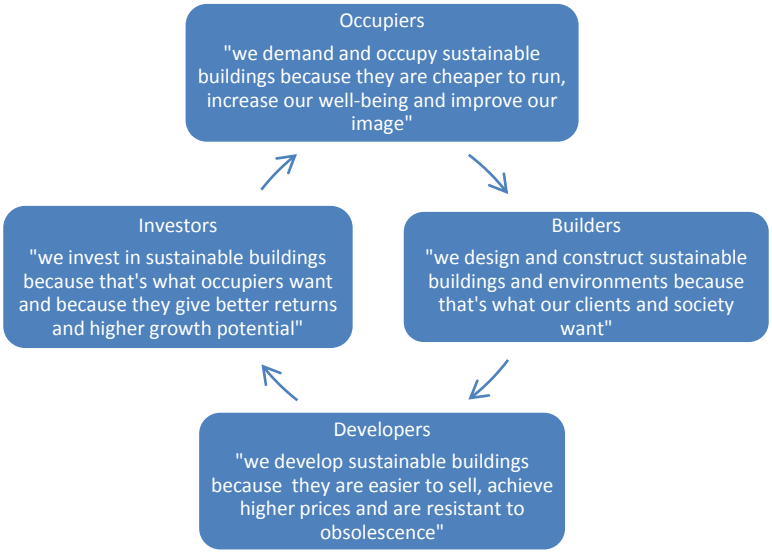
As we have argued earlier, while there has been a surge in the development of and demand for green buildings globally and in Canada, it is likely that some or all of the attitudes/beliefs described above persist and represent a collection of biases that need to be addressed going forward. Also, we must keep in mind that the number of buildings that have been certified in Canada either by LEED/BOMA or others programs represent a very small proportion of the total building stock (a few thousand certifications in total), and all stakeholders concerned must continue to strive to make sure the growth trend continues and existing barriers and uncertainties are addressed.

Some authors have argued that where we need to get to in the real-estate industry is a situation whereby both the demand-and supply-sides purchase and offer green building construction in equal measure. In this scenario, the industry is not beset by the 'circle of blame' but rather characterised by the circle of 'virtue', symbolised by positive feedbacks and supports across the spectrum of stakeholders outlined above (Warren-Myers, 2012, Royal Institute of Chartered Surveyors, 2008).

As can be seen in Figure 1.10, in the virtuous circle the major stakeholders take a positive view of green buildings because it serves their interests and their pursuit of these benefits also support and entice the positive actions of others. Thus, under that scenario, the clientele demand green buildings because they provide operational cost-savings, promote better physical well-being for

occupants, and allow firms to improve their public image. This support from the clientele encourages developers and designers to shift towards green building design and construction because green buildings are easier to sell and achieve higher selling prices. The higher demand from the clientele also encourages investors to lend to green construction companies as these properties are able to capture a higher rate of return and hold greater value-growth potential than conventional properties (RICS, 2008).

Figure 1.10 - The Circle of Virtue (Source: RICS, 2008)



1.4 - Where do we stand in Canada?

In Canada, if we want to move the real-estate industry, clientele, and investors towards embracing more fully green building materials and technologies (towards the circle of virtue), we may then, as a starting point, ask the question as to where the Canadian real-estate market actually stands in the spectrum between the 'circle of blame' and the 'circle of virtue'. A good starting point would be to investigate how green buildings are perceived by the real-estate clientele. Specifically, we can investigate whether they capture higher market-valuations and prices. Indeed, this question relates directly to our discussion above. For instance, if we can capture evidence that there is a 'green premium' in the Canadian real-estate market in terms of higher prices and market-valuations (and lower vacancy rates), then we can at least confirm that the clientele do indeed place a higher value upon green characteristics (or certifications).

Furthermore, this is information which could help builders, developers, and investors in their decision-making processes, possibly leading to greater green building and investment projects.

For instance, consider the "dilemma" facing developers described above. Currently, developers and builders may argue that they would like to ask for or build green; however, investors are lukewarm on these kinds of building developments. This may be because there is a perception amongst investors that the demand for these buildings is not strong enough to justify the potential risks. Indeed, a recent survey by the Canada Green Buildings Council revealed that 39% of the real-estate professionals they surveyed indicated the lack of market-demand as one of their top three concerns (CaGBC, 2014, Pg. 29).

In the world of the virtuous circle (see Figures 1.11 and 1.12), in contrast, the building industry is interested in green building development because there is strong demand for green buildings, and they achieve higher prices. Similarly, with respect to investors, we wish to bring about a future market where it makes sense to invest in green buildings because they are demanded by the clientele and produce higher returns.

Figure 1.11 - The transformation of developers and builders

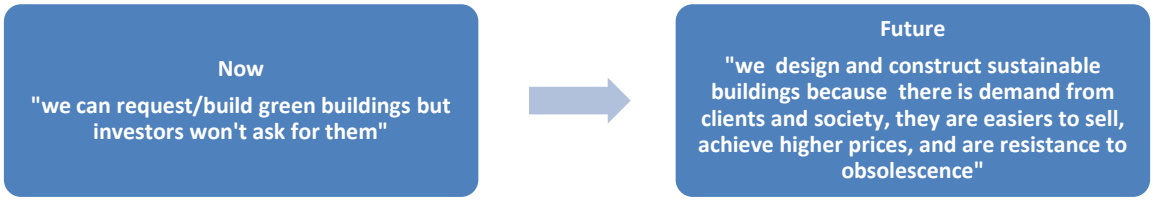
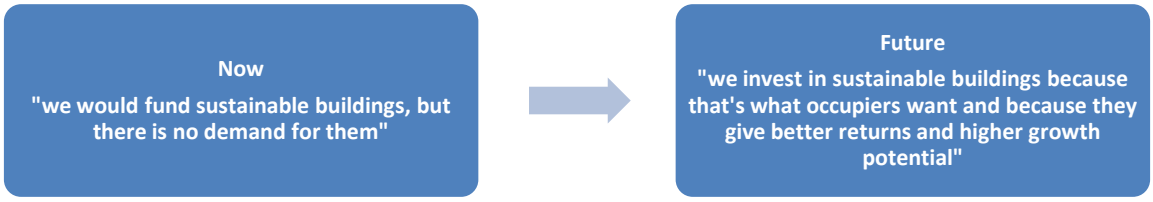


Figure 1.12 - The transformation of investors



However, these transitions we have mentioned need to be based upon sound evidence, and so for the research community capturing this evidence (of a green premium) using high standards of scholarship is crucial if the circle of virtue is to be created in the Canadian real-estate market.

Therefore, studies examining and highlighting the green premiums which these buildings *may* be already capturing could help us with the transition towards the circle of virtue. Furthermore, studies focussing upon green real-estate and their socio-economic performance have been conducted mostly in the European and U.S. contexts (see Chapter.2). In the academic arena, studies investigating whether green premiums exist in the Canadian context are scarce, and none investigate the exact research question related to market-valuation and prices which concerns us. We have seen above that there has indeed been strong green building growth in the country over the last several years, therefore, now is an opportune time to investigate and quantify the existence of any potential green premiums these buildings may be capturing in the market-place.

Furthermore, policy-makers and government ministries at all levels have a vital role to play in helping us transition towards a greener economy, which should include a greener real-estate industry. However, pro-green public policy initiatives are more forthcoming if a critical-mass of *both* technical and socio-economic evidence can be gathered which provide direct evidence that change is not only desirable but is well accepted amongst the populace, and can be justified from multiple perspectives. Therefore, if it can be demonstrated that green buildings do capture higher market-valuations and prices (or lower vacancy-rates), then promoting such real-estate developments is easier, given that the efforts are based on evidence.

Lastly, given the lack of academic studies examining question of the green premium in the Canadian context, now is an opportune time to conduct an inquiry looking into whether the market values to a higher extent green features, through an examination of valuations, prices, and vacancy rates.

1.5 - Key Research Question

In our discussion above, we have repeated the term 'market-value' and 'valuation' numerous times. Before proceeding further we must first define what is meant by market-value. Essentially, the establishment of market-value is the primary task of the valuation professional. While there are various definitions available internationally, they generally conform to the same idea. According to Chappell and Corps (2009), the US Appraisal Institute's definition of market value is a good indicator, it is "the *most probable price*, as of a specified date, in cash, or in terms equivalent to cash, or in other precisely revealed terms, *for which the specified property rights*

should sell after reasonable exposure in a competitive market under all conditions requisite to a fair sale, with the buyer and seller each acting prudently, knowledgeably, and for self-interest, and assuming that neither is under undue stress" (Chappell and Corps, 2009, Pg. 13).

Therefore, we can think of the idea of market-value as a barometer for market-demand since prices are in part an indicator of the demand for a product. If green certifications are appreciated in the real-estate market by the clientele, and they are willing to pay a premium for them, then one would expect the appraiser to incorporate this *higher* demand for green features (or certifications) into the appraisal process resulting in a higher market-value. Furthermore, if green buildings do indeed capture higher market-values, then incorporating these valuations into a regression model will allow us to test the effect of green features (through certification) upon the market-value estimate (a measure of demand). Essentially, we can estimate whether certification exerts a positive and statistically significant effect upon market-value. If that is the case, then we can provide definitive evidence that green certifications do capture higher market-values, because the market appreciates these certifications. Lastly, given that the valuations calculated by municipal/provincial appraisal agencies are the basis for property taxation (see Discussion chapter for greater details), higher valuations for green buildings should result in higher tax revenues for municipal authorities[3].

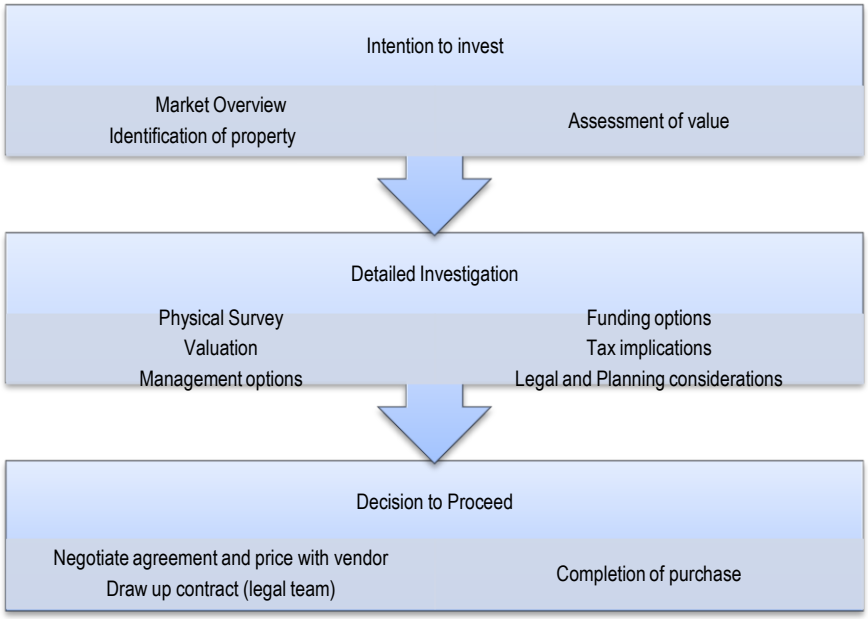
One may ask the question as to why an analysis of this type is needed in Canada, given that green buildings have been on the rise over the past decade. However, it must be understood that although these technologies have been growing, key socio-economic and technical questions still remain with respect to these buildings, of which this thesis attempts to investigate only one. As noted earlier, it is unclear in the Canadian context as to how much of a premium green features and/or certifications actually capture. Furthermore, if these premiums exist (as their growth certainly points towards), in what contexts do they exist? Specifically, we should investigate which markets, sectors, and regions premiums are being potentially realised. In Canada, on the whole, these subjects have not been addressed by the academic community. Lastly, 'negative'

[3] However, it should be noted that higher valuations could result in higher tax burdens for green home-owners. Whether higher tax burdens prevent investments in these properties needs to be investigated as these buildings continue to grow. Over time, if real-estate markets shift and these properties become the 'norm', then such premium should lessen as higher supply and technological improvements drive values lower.

results can also be useful as they would perhaps point towards new avenues for research, public action and/or technological progress.

Lastly, we must note briefly the key role that valuation plays in the investment process. Whether the real-estate investor is an individual or an institution (banks, mutual funds, real-estate investment trusts), the calculation of value plays a key role. Indeed, if we look at the chain of decisions the individual investor must pass through (Fig-1.13), we can see that very early on in the process, an assessment of value must be carried out. Therefore, the importance of getting the valuation 'correct' cannot be over-stated, as it affects the purchasing/investment decision greatly. With respect to our research, this point reinforces the importance of investigating both the effect of green certifications upon market-valuation (our primary research agenda), and the current market-valuation processes and methods used in the broader context of green building development and promotion, a point we will return to later in the discussion chapter.

Fig. 1.13- The real-estate investment value-chain (Source: Isaac and O'Leary, 2011)



Before stating our research question, we will sum up the discussion outlined up to this point. First, we have argued that the buildings sector has a significant environmental footprint when the use of energy, water, and greenhouse gas emissions is taken into account. This footprint is predicted to continue, despite newer technologies and efficiency gains. Therefore, any future efforts towards energy/water conservation and greenhouse gas mitigation must address resource

use in this sector. One of the ways better conservation outcomes may be achieved in real-estate is through the promotion of green buildings (those which have achieved environmental certification, or perform beyond the building code guidelines)[4].

We have also illustrated that green buildings have been growing in Canada in recent times, due to a host of socio-economic and political drivers. Because of the advantages green buildings offer, ideally, we would like to push the real-estate industry to resemble more the circle of virtue. One key avenue through which we can promote green building development is to investigate and possibly confirm whether these buildings capture higher values and prices[5], an important indication of greater demand for green features/certifications.

Indeed, if this evidence exists and can be captured, the information can help alleviate some of the uncertainties that persist in the market with respect to the actual strength of green building demand. Such evidence could encourage a better response from particularly developers/builders and investors. Furthermore, there is also a lack of Canadian-based academic research that has focussed upon these questions. Indeed, given that green buildings have been growing nationally over the past several years, now is an opportune time to conduct such an inquiry using robust quantitative methods.

Therefore, the research question we have developed, given the industry and academic needs and gaps described above is, "Do green buildings capture higher market-valuations and prices in Canada?"

In order to answer this question, we will be presenting three major statistical analyses utilising publicly-available Canadian data. Our study will begin with a review of some of the key 'hedonic' studies which have attempted to answer similar questions as the one we have ourselves with (Chapter 2). Following this, we will outline our hedonic regression methodology for both the residential and commercial models (Chapter 3). This chapter is then followed by the hedonic model results for the residential and commercial regression models (Chapter 4). In order to cross-check our results we will also present a non-linear model which reinforces our conclusions

[4] In addition to this, we may also promote the construction of smaller dwellings that are more energy-efficient and help curb urban sprawl.
[5] Higher prices can also compensate builders for any additional construction costs they may incur from green building.

(Chapter 5). Moving on, we examine another metric by which we can measure demand, commercial office vacancy-rates. Specifically, we compare, using chi-square and means tests, the vacancy-rates between green and non-green properties (Chapter 6). Our last statistical exercise involves using 'paired-analysis' techniques (borrowed from the Appraisal Sciences) to see if a price-differential exists between three green properties and their comparables in Ontario (Chapter 7). Lastly, we will present a discussion (Chapter 8) of our findings followed by a brief conclusion (Chapter 9).

2.0 - Literature Review Chapter

Our research question is concerned with investigating whether there is a green premium in terms of market-valuation (or assessed value) in the Canadian real-estate market. The academic community and real-estate professionals have produced numerous analyses evaluating the economic potential and performance of green buildings. Specifically, there exists a wide range of papers utilising life-cycle costing, discounted cash-flow, and other cost-benefit analytical techniques to evaluate the economic performance of green properties. Furthermore, numerous analyses have been undertaken measuring the willingness-to-pay for green features/certifications. Another group of studies have focussed upon the effects that certification have upon selling/rental prices (these studies are reviewed in this chapter). Most of these studies have been conducted in non-Canadian contexts.

The research question which concerns us allows us to approach the subject of green features and more specifically, green certification schemes from the demand-side.[6] Our primary interest is to examine how the market values green certification through an analysis of valuation assessments, which is in theory also a reflection of market demand. On the demand-side, there are two major analytical frameworks which divide the academic literature to date, stated and revealed preference-techniques. We will now turn to provide a description of these studies.

2.1- Literature Review: A Summary of Revealed Preference Techniques

A large body of literature has been developed to try and capture the evidence of the oft-argued 'greater' value of green buildings and features (often referred to as a 'green' premium). The techniques used can be generally grouped into either the 'stated' preference or the 'revealed' preference categories. Most of the stated preference literature looks at the willingness-to-pay of potential clients for more expensive green building features, and they have been carried out in a wide variety of jurisdictions. These studies have focussed upon consumers in Canada (Spetic et

[6] Note: Not all Hedonic models incorporate the 'certification' variable to test the effects of 'green' features. For instance, Wang (2010) and Jim and Chen (2007) use binary (dummy) variables to indicate the presence/absence of green spaces close to a property, in addition to the presence (or not) of public transportation. Also, Chau et al. (2010) include variables indicating energy and water-savings, noise, and air-quality into their modelling. Similarly, Achtnicht (2011) uses the energy-saving potential of properties and carbon-dioxide savings to test green characteristics. Lastly, Leung et al. (2005), use the change (or improvement) in energy-consumption from the thermal and lighting components.

al, 2005), Germany (Achtnicht, 2011), China (Jim and Chen, 2007), and Hong-Kong (Yau, 2012, Leung et al, 2005, Chau et al., 2010).

However, willingness-to-pay does not necessarily translate into actual payment. Most of the studies noted above look at the question of green demand by using choice-experiment techniques, whereby the respondent is given different bundles of goods and features to choose from, and each bundle comprises different attributes or green features (or none). From a valuation and investment standpoint, what is more important is not the preferences people express under hypothetical situations, but rather the decisions people actually make in the real market as shown through their purchases and actions. This brings the discussion towards the idea of 'revealed preferences'.

There are two possible techniques that can be utilised under this category of valuing green attributes, hedonic pricing and the travel cost method (Hanly and Barbier, 2009). The latter method does not relate specifically to our research question since we are not interested in how far people travel or relocate to live in a green building. On the other hand, the hedonic pricing literature is voluminous and various authors have used it to measure the effect(s) of green attributes on the selling prices of buildings. Some of the key and comprehensive studies utilising the hedonic framework (applied through regression modelling) will be the focus of this chapter.

According to hedonic pricing theory, the prices of green buildings (like other products) are determined by various product features, socio-economic and environmental factors (see Methodology). To decompose the effects of these attributes, the use of regression analysis techniques is common, whereby the price of the building/rental rate is the dependent variable and the attributes of the building, such as location, dimensions, size, policy factors, green features, etc, are the explanatory variables[7]. Many studies have utilized this method to gauge the effect of green features and test their statistical significance (see discussion below).

In such studies, the co-efficient in a regression equation (usually) is an indication of the average effect that the green feature will have on the price, and so shows the value of that feature. In the

[7] An alternative method of comparing green and non-green properties is to conduct a comparison of means test (of prices, valuations, vacancy rates, etc.). However, the key is to understand the effects of green features when 'other' variables are taken into account, the use of multi-variable regression analysis allows us to understand the 'value-added' of certification (or green features).

hedonic models described below the effect of green certification is evaluated on dependent variables such as sale prices, rents, market-valuations, and other financial indicators (return on income, net-operating income, etc).

Revealed Preference - Hedonic Model Studies

Fuerst and McAllister (2011) conducted a study using regression methods for the commercial sector in the United States. The objective of their study was to investigate whether environmental labelling was a contributing factor to positive price effects. In their paper they argued that there are lots of studies looking into the willingness-to-pay for green features. However, there is a relative lack of revealed-preference studies (ibid, 2011).

The data for their study were obtained from the Co-Star national commercial data-base. Their original sample consisted of 2688 office buildings, of which 313 were LEED buildings, 2111 were Energy-Star properties, and 264 had both certifications. The comparables for each subject property were selected from the same office district, and each subject was paired with at least ten comparable properties. The transaction prices (rents and selling prices) covered the period 1999-2009.

Their regression equations consisted of the logarithm of selling price, logarithm of rent, and the occupancy-rate as the dependent variables, while the explanatory variables were the certification (binary) variable, age, quality (broken into indicator variables), amenities (broken into indicator variables), the type of lease, capital market conditions (indicator-variables), and the submarket. The table below provides more details outlining the explanatory variables used in their model.

The authors estimated three sets of regression models with the data and variables shown above. The first set involved using the logarithm of average rental prices per square-foot as the dependent variable. The second set of regressions used the logarithm of sale-price per square foot as the dependent variable. Both these sets were modelled using ordinary-least squares (OLS) and 'robust' regression techniques. The third set of regression models used the occupancy rate as the dependent variable, and the regression methods used were OLS and fractional-logit. According to Fuerst and McAllister (2011), fractional logit models are better suited for modeling fractional dependent variables (such as the occupancy rate) which are bounded by zero and one (Fuerst and McAllister, 2011).

We can see below (Table-2.1) that a green premium does seem to exist in the U.S. commercial markets studied. For both the OLS and robust models, certification is statistically significant at the 1%, 5%, and 10% levels. When it comes to rental rates, being certified adds 4 to 9% to rental prices. For sale prices, the premium is much higher, 18 to 29%. However, we also observe that for occupancy rates, only Energy-Star buildings capture a 1% premium, with lower occupancy rates associated with LEED and dual-certified buildings.

Table 2.1

	OLS	**Robust**
1- Dependent Variable : Log Rental Rates		
Energy Star	0.04***	0.03***
LEED	0.05***	0.04
Dual Certified	0.09***	0.09***
R-squared	0.60	
2- Dependent Variable : Log Sale Prices		
Energy Star	0.18***	0.18***
LEED	0.25***	0.25***
Dual Certified	0.29***	0.28***
R-squared	0.48	
3- Dependent Variable : Occupancy	**OLS Co-efficient**	**Fractional Logit**
Energy Star	0.01***	0.03***
LEED	-0.05**	-0.06***
Dual Certified	-0.02*	0.00
R-squared	0.25	-
***significant at the 1% level, ** significant at the 5% level, *significant at the 10%		

Source: Fuerst and Mcallister, 2011.

A recent study by Chegut et al. (2013) examined, over a 10-year period, the effect that green buildings had on commercial rents and home prices in a given London (England) neighbourhood. In their model, an ex-post transaction-based (post-sale) hedonic framework was used to measure the effect of BREEAM-rated office buildings on sale prices and rents in specific neighborhoods. Their objective was to investigate the economic dynamics behind the financial performance of London's environmentally certified commercial building stock.

They constructed a data-base of properties over the 1999-2009 period using the Co-Star Focus data-base of rents and property transactions. Using the data-base, site-visits, real-estate management company information, and other online tools (EMPORIS, EGi, and Real-Capital Analytics), they created a data-base comprising the rental statistics of 1149 buildings. In addition to this sample, a further 2103 buildings including 68 BREEAM certified buildings were analysed for the sales transaction (selling price) model.

In the study, the authors used two sets of models, one where the dependent variable was the logarithm of rents per square metre, and in the other the dependent variable was the logarithm of

sale price per square metre. The analysis was carried out in four phases (or regression models) for each of the dependent variables. In all cases, simple OLS modelling methods were used.

In the first phase, the explanatory variables were rental size, age, storeys, amenities (indicator variables), renovation (dummy), quality (indicator variables), transport (indicator variables), and time-fixed effects. In the second phase, control (indicator) variables were added to incorporate rental contract features into the model. In the third phase, indicator variables for the local supply of green buildings were added. Lastly, an interaction term combining the certification variable and the local supply of green buildings was added to the model. This was to test whether the effects of certification are dependent upon the local supply of green buildings. The table below provides an overview of the explanatory variables used in the modelling.

We can observe from Table-2.2 below that their study found that green buildings fetch substantial rent and sale premiums in the London real-estate market. For rental prices, the premiums are 22-31% (and statistically significant at 1%). The sale price premiums are 17%-37%, and significant at the 5% and 10% levels.

Table 2.2

	Regression 1	**Regression 2**	**Regression 3**	**Regression 4**
	BREEAM	**BREEAM**	**BREEAM**	**BREEAM**
1- Dep Variable : Log Office Rents per square metre, n=1149	0.28 (R-square = 0.57)***	0.25 (R-square =0.59)***	0.22 (R-square = 0.60)***	0.31 (R-square=0.61)***
2- Dep Variable: Log Sale price per square metre, n=2103	0.24 (R-square = 0.21)***	0.18 (R-square = 0.21)**	0.17 (R-square = 0.22)**	0.37 (R-square = 0.22)***
* significant at 10%, **significant at 5%,***significant at 1%				

Source: Chegut et al., 2013.

Dermisi (2009) has examined the effect that LEED ratings have on office property assessed and market-values in the U.S. This is the hedonic model which most closely resembles our modelling approach and research question since the dependent variable is the market-valuation provided by assessment agencies. The two dependent variables in her study were total assessed values and total market-values.

According to Dermisi (2009), the total-assessed value is the "amount for both land and structures assigned by the local assessor for tax purposes.....in most cases, a ratio is applied to estimate assessed value based on the full cash or fair market-value of the property" (ibid, P. 46). The total market-value is also estimated by local assessors and it is "usually a competitive sale price for

the property considering existing market conditions" (ibid, Pg.46). The author used these variables as the dependent variables in her hedonic models since obtaining transaction prices was a problematic task. Plus, for newly constructed homes, selling prices may not exist as the property may not have changed hands. Lastly, there is little literature globally that has investigated this particular research question (ibid, Pg. 25).

The data-set was created using information from several sources including the Co-star database, the U.S. Green Buildings Council, and city assessment agencies. The valuation and explanatory variable data were collected from February 2009, through to the summer of 2009, resulting in a total sample of 351 buildings across 36 states. Out of that sample of 351 commercial properties, market-values were obtained for 275 properties and assessed values were obtained for 266 properties. Also, Class A properties dominated the building sample[8].

Out of the 351 properties gathered, 200 of the buildings achieved LEED for New Construction, 85 buildings achieved LEED for Existing Buildings, 51 buildings achieved LEED Core and Shell, 6 buildings achieved LEED for Commercial Interiors, and 9 had no certification. The explanatory variables are described in the table below.

There were three sets of regression models estimated by Dermisi in this paper. The first, labelled 'Equation-1', was a simple robust Ordinary Least-Squares model where the dependent variables were the logarithm of total assessed and market-values. The explanatory variables in this case were the Energy-Star designation, rentable building area, year built, Class A (binary), multiple-tenant (binary), private ownership (binary), and LEED (broken into type and level of designation). The results for the Equation-1 models are illustrated in the table below. In the first two sets of regressions, the effects of Energy-Star and LEED New Construction upon assessed and market-values are examined. In the third and fourth regressions (under Equation-1), the effects of LEED for Existing Buildings are estimated. Lastly, the last two regression models (under Equation 1) estimate the effects of LEED Core and Shell upon valuations (see Table-2.3).

The statistically significant effects, when Equation-1 results are examined, demonstrate that Energy-Star certification contributes to an average premium of 98% and 79% in assessed values,

[8] For a description of the different classes of commercial buildings see Descriptive Statistics -Commercial (Chapter 4.2.1).

and 90% in market-values. The LEED for Existing Buildings (Silver) brings about an average premium of 63% in assessed values. However, the LEED Core and Shell (Platinum) actually contributes to lowering Market-Value by 38%, while the LEED Core and Shell (Certified) designation lowers assessed-value by 169%. These values are significant at the 5% and 10% levels. However, some of these 'extreme' values cast a certain degree of doubt upon these results and/or the modelling techniques utilised in this study.

Table 2.3

Equation 1 Models	**1 - AV 1**	**2- MV1**	**3 - AV1**	**4-MV1**	**5-AV1**	**6-MV1**
Energy Star	0.98**	0.90**	0.79**	0.79	0.99	0.92
LEED NC & Platinum	-0.46	-0.12				
LEED NC & Gold	0.28	0.25				
LEED NC & Silver	-0.31	-0.32				
LEED NC & Certified	-0.18	-0.14				
LEED EB & Platinum			0.21	-0.08		
LEED EB & Gold			0.54	0.38		
LEED EB & Silver			0.63***	0.44		
LEED EB & Certified			-0.30	-0.08		
LEED CS & Platinum					-0.02	-0.38**
LEED CS & Gold					0.25	0.24
LEED CS & Silver					0.32	0.23
LEED CS & Certified					-1.69***	-0.57
R-Squared	**.203**	**.258**	**.206**	**.255**	**.21**	**.251**

**significant at the 5% level, ***significant at the 10% level.

Source: Dermisi, 2009.

There were two other regression models which we will lightly touch upon, as they do not relate to our research question and methods in a significant manner. However, the regression technique used by Dermisi for those models should be mentioned and assessed for the sake of thoroughness. Dermisi argues that simple OLS procedures do not account for geographic location such as the state in which the property is located nor the metropolitan statistical area. In order to incorporate geographic information as an explanatory variable into the modelling, the longitude and latitude of the property in question are utilised to incorporate a 'spatial weight-matrix' variable into the second regression equation. This procedure allowed for the testing of whether there was a spatial error associated with the OLS model. In this case the log of assessed and market-value was regressed upon hedonic characteristics as well as the spatial weight-matrix (ibid, Pg. 32-34).

Eichholtz et al. (2010) conducted another regression-based hedonic study for commercial buildings in the U.S. They tested the effects of Energy-Star and LEED certification on a total sample of over 8105 commercial properties. Using the Co-Star data-base, 1360 green buildings

were identified. Out of this sample, 286 properties were certified by LEED, and 1045 were certified by Energy-Star, and 29 were certified by both LEED and Energy-Star.

For the 1360 green buildings, information about building characteristics and monthly rental prices (the dependent variable) could be found for 694 of them, and 199 of these were sold over the 2004-2007 time-period. In order to find comparables for the green buildings, Geographic Information Systems tools were employed. In the final sample, there are a total of 8105 commercial buildings (both green and control buildings), with 1813 buildings having been sold (both green and control). The full list of explanatory variables is presented in Table-2.4 below.

There were three sets of models estimated in this study with each phase in-turn incorporating five different regression modelling exercises. For the first set of regression models the dependent variable was the logarithm of rent per square foot. The second set of models used the logarithm of effective rent per square foot as the dependent variable. Lastly, the third set of models used the logarithm of sale price per square foot as the dependent variable. In all cases the OLS method was utilised for calculating the regression estimates.

In each set of models there were five regressions estimates undertaken. In the first set of regressions the dependent variable was regressed on building quality (class, size, fraction occupied), net contract (dummy), employment growth, and whether the building had a green rating (binary). In the second regression exercise, the effects of the green rating was broken up to indicate whether the building was Energy-Star, LEED, or neither. In the third model, only the green rating was included to indicate a green building, and age effects were added. In the fourth model, only the green rating was included with the number of storeys and amenities being added. In the fifth and last model, no green certification variables were added, but other physical and economic variables were included. Given that this last model did not incorporate green features or certification, it is of little concern vis-a-vis our research question and is not described in Table.

Table-2.4 shows that when the dependent variable is the rent per square-foot, having a green rating enhances prices by an average of 2.8% to 3.5% (statistically significant at the 1% level). The Energy-Star label brings about a premium of 3.3%, also significant at 1%. We can also see that the effects of green labels are even higher when the effective rent per square-foot is modelled. Lastly, when the sale-price is modelled, the premium rises to approximately 16-17%

for a green certification, and 19% for Energy-Star. Most of these figures are significant at the 1% level. The performance of LEED is much lower with only a 9.4% premium on effective rent, but significant only at the 10% level.

Table 2.4					
	1	**2**	**3**	**4**	**5**
1- Dep variable : Log rent per sq-foot					
Green Rating	0.035***		0.033***	0.028***	
Energy-Star		0.033***			
LEED		0.052			
Adjusted R-square	0.69	0.69	0.69	0.69	
2- Dep variable: Log effective rent per sq-foot					
Green Rating	0.100***		0.097***	0.079***	
Energy-Star		0.100***			
LEED		0.094*			
Adjusted R-square	0.42	0.42	0.42	0.43	
3- Dep variable: Log sale price per sq-foot					
Green Rating	0.168***		0.158***	0.165***	
Energy-Star		0.191***			
LEED		0.113			
Adjusted R-square	0.35	0.35	0.36	0.37	
Source: Eichholtz et al., 2010. *** significant at 1%, **significant at 5%, *significant at 10%					

Another analysis in the commercial space was undertaken by Wiley et al. (2010) which examined the relationship between energy-efficient design and the rents achieved. They hypothesized that if green buildings demonstrate superior rent and occupancy performance in the leasing market (by way of certification), then that should translate to premiums in the sales market as well due to the potential of earning higher rents, higher occupancy over time and lower operating expenses (ibid, Pg. 232).

In order to carry out their hedonic analysis of commercial properties in the United States, they obtained leasing data from the Co-Star Group for Class A office properties in 46 different markets across the country. The first set of data was collected from Co-Star as of January 9, 2008 and included the current leasing information for a national sample of Class A properties. The study focussed upon Class A properties because this is the class of property that is, according to the authors, the most responsive to changes in technology (ibid, Pg.234). In total, as mentioned earlier, 46 office markets were included and only properties with current leasing and occupancy data were accepted. These conditions resulted in a total sample of 7308 properties for the rental analysis portion of the study.

For the modelling of sale prices, a second set of office building sales data were obtained from the Co-Star data-base of 25 office markets, with information available on the sale prices of both

LEED and Energy-Star properties. Only listings which included complete information on property size, age, and date of sale was included, and this resulted in a sample of 1151 properties for the sale price-model. There were three major sets of models tested by the authors with the logarithm of rent, the occupancy rate, and the sale price as the dependent variables.

The first models regressed rent upon LEED certification, Energy-Star certification, lease-type, age, maximum-contiguous area, and the occupancy-rate. The second set of models regressed the occupancy rate upon lease-type, age, maximum-contiguous area, average rent, LEED and Energy-Star certification. Lastly, the third set of models regressed the selling price upon age, building square-footage, sale-date, LEED and Energy-Star certification, and interaction terms (interacting LEED certification and building-size and Energy-Star and building-size). The interaction terms were included to test whether the effects of LEED and Energy-Star certification upon valuations depend on building size.

We can see from Table-2.5 below that a green premium exists for a building's average rent. The LEED certification adds a premium of 15-17%, while the Energy-Star label adds 7-9%. When the sale prices are modelled, the certification variables actually show a negative effect upon sale prices (but not significant), while the interaction effects are positive and statistically significant.

Table 2.5

	1st Set		**2nd Set**	
	OLS : Dep variable - Log average rent	**2SLS average rent**	**OLS : Dep variable- Occupancy rates**	**2SLS: Occupancy Rates**
LEED	0.1516***	0.1730***	16.20***	17.92***
Energy-Star	0.0734***	0.0862***	10.18***	11.03***
R-squared	0.632	0.584	0.463	0.459
3rd Set - Dep Variable: Sale price	**OLS**	**t-stat**		
LEED	-7,588,562	-0.45		
Energy-Star	-10,546,043	-1.59		
LEED Building * Building sq ft	129.18***	3.45		
Energy-Star * building sq ft	29.71**	2.20		

Source: Wiley et al., 2010.
* significant at 10% level, **significant at 5%, ***significant at 1%

Kok and Kahn (2012) looked at the effect of green labels on sale prices for the California residential market. They conducted a hedonic analysis of approximately 2.5 million homes sold in California between 2007 and 2012. They utilised transaction (sale prices) from the state of California for over 8000 buildings certified by Greenpoint, Energy-Star, and LEED for Homes. In addition to this green sample, they also found a control sample of 1.6 million non-certified homes that were used as comparables in the modelling.

Additionally, the authors hypothesized that the demand for certified homes is greater in hotter climates, and so climate was also factored into the regression modelling in the latter stages. Another factor taken into account was the ideology of the consumer in a particular neighborhood, signified by the percentage of hybrid car registrations in the particular neighborhood being modelled.

There were three sets of regression models performed by Kok and Kahn (2012), each adding variables and building upon the results of the previous model. In all the models, the dependent variable is the home sale price for building (i) in cluster (j) in quarter (t). In other words, the sale price of a particular building in a certain neighborhood at a certain time forms the dependent variable. In all cases, the modelling technique used was OLS (see Table-2.6).

In the first set of regression models, the green rating is only evaluated in the fourth regression model, and only as a binary variable. From the first to the fourth set of estimates, variables are added progressively. The first set of estimates only incorporate size, bathrooms, bedrooms and garages, while the fourth contains all the variables displayed in the table with the exception of the interaction terms.

In the second set of regression models, the certification variable is broken up into its constituent parts (Energy-Star, Greenpoint, and LEED for Homes), as can be seen from columns one to three below. In addition to this, for the fourth set of estimates (column 4) interaction terms were also included, interacting green certification (binary) with the year of certification to examine whether the effects of certification depended upon the year certified. The results indicate that the more recent certifications have significant and positive effects. These models also incorporate the other characteristics displayed in the table above. In the last set of regression estimates, the effects of Green-point, Energy-Star, LEED for Homes, and a binary green certification variable are tested for more recently constructed homes.

When only the binary certification variable is tested, the premium to sale price is almost 12%. Breaking the certification variable down further, we can see that certification results in a premium of 14.5% for Energy-Star homes. For recently constructed homes, the certification variable results in a premium of 8.7%, while Energy-Star homes fetch a premium of 11.2%.

However, no premiums can be found for the LEED certification. These results are also significant at the 1% level.

Table 2.6				
1- Sale Prices (2007-2012)	**1**	**2**	**3**	**4**
Green Rating (1=yes)				0.118***
Adjusted R-square				0.871
2- Green Labels, Sale Prices				
Energy-Star (1=yes)	0.145***			
Greenpoint (1=yes)		0.024		
LEED for Homes (1=yes)			0.077	
Adjusted R-square	0.864	0.864	0.864	0.864
3- Recently Constructed Homes				
Green Rating (1=yes)	0.087***			
Energy-Star (1=yes)		0.112***		
Greenpoint (1=yes)			-0.016	
Leed for Homes (1=yes)				0.097
Adjusted R-square	0.899	0.899	0.899	0.899
* significant at 10%, **significant 5%, ***significant at 1%				

Source: Kok and Kahn, 2012.

Pivo and Fisher (2010) use hedonic modelling to examine the effect of certification (Energy-Star) in the U.S. commercial sector. In their formulation, it is hypothesized that green features which positively affect occupancy, rent, or operating expenses should affect the Net-Operating Income positively (ibid, Pg.245). As such, they will be reflected in higher sale prices.

Their sample of commercial properties consisted of buildings listed in the National Council of Real-Estate Investment Fiduciaries data-base. The quarterly data were obtained over the 1999-2008 period, and resulted in a total final sample of 1199 properties. Using only OLS, they modelled a series of financial indicators (all in logs) indicating the financial performance of a particular property for a given year, upon a set of regressors indicating the responsible property features of the building, the national office market conditions, the state of the economy in the region of the building in a particular year, the regional location of the property, accessibility features of the property, the quality of the property, and lastly, the cost of government services used by that particular property in a particular year.

Table-2.7 shows that the authors estimated five sets of regression models, each with their own dependent variable converted to logs. The dependent variables utilised were net-operating income in the first model, market-value per square-foot in the second, income-return per year in the third, appreciation return per year in the fourth year, and total return per year in the last.

The results below show that the Energy-Star label brings about a premium of 2.7% for net-operating income, 8.5% for market-value per square foot, but also a negative effect of 0.5% on income return per year. The first two results are significant at the 5% and 0.1%.

Table 2.7					
Property type	**NOI per square feet**	**Market-Value per sq. ft**	**Income return per year (cap rate)**	**Appreciation return per year**	**Total Return per Year**
Energy Star	2.7**	8.5****	-0.5****	0.0	-0.5
Suburban Regeneration	-3.9	-3.3	-0.3	-0.2*	-2.5*
CBD Regeneration	8.2***	6.7**	0.5*	-0.0	-0.5
Suburban Transit	1.5	10.6****	-0.4****	0.1**	0.7
CBD Transit	-2.5	9.1****	-1.5****	0.0	-0.4
* significant at the 10%, **significant at the 5%, ***significant at the 1%l, ****significant at the .01%, CBD=Central Business District					

Source: Pivo and Fisher, 2010.

In sum, the hedonic pricing framework through regression modelling has been widely utilised to demonstrate the effect that green certification has had on house prices in various markets. So far, the results have been on the whole very positive, in that the studies have generally shown that green certification is statistically significant and is associated with higher prices and rents. Hence, the green 'premium' does seem to exist in the markets studied.

2.2 - Summary and Critique of Literature Review

We have examined some of the key academic papers that have investigated the effects of certification upon variables signifying building value, using hedonic (regression) methods. The papers included in this chapter were selected on the basis of four major criteria. The main research question of the paper had to have as its aim the testing of the 'value' or 'effect' of green certification. Secondly, the dependent variable had to be price, market-valuation, or some indicator signifying economic (demand) potential. Thirdly, the methods utilised in the study had to conform to the ideas of the 'hedonic' theoretical framework, as we were interested in 'revealed' preferences. Lastly, most of the papers discussed were chosen based on the numerous citations they had received in the domain of 'green' hedonic real-estate literature.

Some of the key results are illustrated in Table 2.8 below. Almost all the papers investigate the existence of the green premium for the commercial sector, with the exception of the study by Kok and Kahn (2012), which focuses upon the California residential market.

We can see that the rental and sale prices are utilised as the dependent variables in the majority of papers. It is only Dermisi (2009) who has investigated the effect of certification upon assessed

and market-values. However, her analysis did not yield strong evidence for a green premium as most of the certification variables were not significant. Furthermore, the premiums estimated by her study are also very high (over 60%-98%), and in some cases the negative effects of certification seem excessive (e.g., 169%). Therefore, we must be cautious in interpreting those results.

The explanatory variables generally include obvious hedonic features such as the quality of the building, the amenities within the building and close by, and in some cases, the lease-features (Fuerst and Mcallister (2011), Wiley et al. (2010), and Chegut et al.(2013)), and investor/tenant types (Dermisi, 2009). The incorporation of economic (market-conditions) and financial variables have also been undertaken by Eichholz et al. (2010), and Pivo and Fisher (2010). In some cases, interaction terms have also been utilised to estimate whether certification effects are dependent on time of certification (Kok and Kahn, 2012), or building-size (Wiley et al., 2010).

In terms of the techniques utilised, the vast majority of authors have relied upon the OLS method to estimate their results, with a few exceptions. Fuerst and Mcallister (2011) utilised robust-regression and fractional logit models to estimate their results in addition to OLS. Dermisi (2009) attempted to account for geographic effects by incorporating a spatial weight-matrix, in addition to OLS. Lastly, Wiley et al. (2010), used sum-of-least squares in addition to OLS. The choice of regression model is dependent on the research question at hand. Hence, the OLS (linear) model is appropriate if the relationships between the dependent and explanatory variables are linear (see Results Chapter). If the other key assumptions of OLS modelling are met (see Results Chapter), then this is a statistically viable tool for mapping relationships. Furthermore, depending on the data and the analytical rigor required, in addition to OLS other non-linear models may be added for cross-comparison and validation of the results obtained from the former (as some of the authors noted above have done).

However, the drawbacks of the OLS method are that while it allows for the construction of "average" relationships, this may not apply in all cases (De Veaux, et al., 2012). For instance, in the case of real estate, the effects of green features on economic variables may be different in a given local market due to local socio-economic and political dynamics. Also, OLS (or regression modelling) in general cannot capture the intrinsic "quality" of a home which may best be appreciated and evaluated through a detailed home inspection. Therefore, in some cases, the

"average" relationship built through OLS modelling may not apply. As such, one has to be cognisant of these limitations. However, it is possible to incorporate local dynamics to some extent through the use of more (or thorough) explanatory variables. For the purposes of our research question, the OLS technique allows us to test the effects of certification upon market-valuation in a 'general' sense.

To conclude, as to the question of whether a green premium was found, the vast majority of the papers support the existence of a green premium (through certification) upon sale and rental prices, and some of the other financial variables modelled[9]. While there is a lot of variation in terms of the estimates obtained (some as low as almost 3%, while other estimates are well into the double-digits and show a premium of almost 100%), we can assert that at least for the markets examined (mostly within the U.S. commercial sector), there is likely a green premium associated with certification. This is reinforced by the fact that the vast majority of the positive results are also significant at the 5% level or lower.

[9] Some of the main reasons put forward as to why these premiums are being achieved in green buildings include lower discount rates leading to increased valuations (Pivo and Fisher, 2010), lower energy-usage leading to lower operating costs (Chegut et al.(2013), Wiley et al. (2010)), higher levels of prestige associated with certification (Chegut et al. (2013), higher occupancy rates (Wiley et al. 2010), the value of 'intangibles such as health and productivity ((Kok and Kahn (2012), Chegut et al. (2013)), and inhospitable climates (Kok and Kahn, 2012).

Table 2.8 Listing of Model Results and Explanatory Variables				
Author	**Dependent Variables**	**Explanatory Variables**	**Regression Techniques**	**Green Premium?**
Fuerst and McAllister (2011)	Rent, sale price, occupancy	Certification, quality, physical attributes, amenities, lease-features	OLS, Robust regression, Fractional-Logit	**Rent** 4-9% **Sale prices** 18-29% (U.S.)
Chegut et al. (2013)	Rent, sale price	Certification, lease-features, quality, transport, buyer-type	OLS	**Rent** 22-28% **Sale prices** 17-37% (London)
Dermisi (2009)	Assessed-value, market-value	Certification, size, year, class, tenant-type, owner-type	OLS, Spatial weights	Energy-Star: Assessed-value (98%-79%), Market-value (90%) LEED EB (silver, 63%), LEED CS (platinum, -38%, certified, -169%)
Eichholtz et al. (2010)	Rent, effective rent, sale price	Certification, physical attributes, economic, amenities	OLS	**Rent:** green rating 2.8-3.5%, Energy-star 3.3% **Sale prices:** green rating 16-17%, Energy-star 19%
Wiley et al. (2010)	Rent, occupancy-rate, sale price	Age, size, lease-type, Certification, maximum-contiguous area	OLS, Sum of Least-Squares	**Rent:** LEED 15-17%, Energy-star 7-9% **Sale price**s: not significant
Kok and Kahn (2012)	Sale price	Certification, size, bedrooms, bathrooms, garages, age, renovation, views, distressed sale, pool, air-conditioning	OLS	Green rating 11.8%, Energy-Star 14.5% Recent Homes: Green rating 8.7%, Energy-Star 11.2%
Pivo and Fisher (2010)	Net-operating income, market-value, income return, appreciation return, total return	Responsible property investment features, market-conditions, regional economic variables, occupancy, location, accessibility, quality, cost of government services	OLS	Energy-Star: Net-operating income-2.7%, Market-value-8.5%, Income-return -0.5%

2.2.1- Analysis of explanatory variables used in Green 'Hedonic' Variables

Tallying up the key explanatory variables used in our studies (Table 2.9) we can see that with respect to commercial properties the square footage of the property is the most oft-used explanatory variable, followed by the number of stories, whether the property was renovated, and the age of the property. Other important variables include the fraction of the property occupied, the class, and the economic conditions in place in those markets (through employment growth).

In our literature review, we reviewed only one study (Kok and Kahn, 2009) that modelled the green premium for the residential sector. The variables used in that study (bathrooms, bedrooms, garage, distressed sale (binary), pool, and cooling system) are similar to other residential hedonic models. Baranzini et al. (2008) argue that generally, hedonic models incorporate the basic physical characteristics of the home (as done by Kok and Kahn, 2009). Furthermore, Sirmans et al. (2006) conducted a 'meta-analysis' of hedonic studies from the U.S. and found that the 9

housing characteristics most utilised in hedonic studies were square-footage, lot-size, age, bathrooms, bedrooms, garage (binary), swimming pool (binary), fire-place (binary), and the presence of air-conditioning (binary).

For the commercial sector, the key variables mentioned in Table 2.9 below are some of the same ones we analysed for our study (with the exception of occupancy rate and the financial/economic variables). With respect to the residential analysis, we considered the most of the variables outlined above by Sirmans et al. (2006) above. The methodology chapter outlines in greater detail from where the data were obtained and the processes used to transform them to suit our analyses. Furthermore, the required statistical diagnostic techniques are described in Chapters 3 & 4.

Table 2.9 Analysis of Explanatory Variables

Commercial Variables	**Number of Studies**
Size (Square footage)	6
Stories (number of)	4
Renovation (Binary)	4
Age	4
Fraction Occupied	3
Class (Binary)	3
Employment Growth (%)	3
Total Return on property	2
Central Business District (Binary)	2
Plot-size (square footage)	1
Conference-Suite (Binary)	1
Atrium (Binary)	1
Parking (Binary)	1
Bank (Binary)	1
Fitness Center (Binary)	1
Air-Conditioning (Binary)	1
Onsite Manager (Binary)	1
Bus stop/Rail (Binary)	1
Convenience Store (Binary)	1
Food Services (Binary)	1
24/7 Access(Binary)	1
Utility owner/tenant (Binary)	1
Single Tenant (Binary)	1
3-month treasury bill rate	1
Corporate Bond-rate	1
Yield curve	1
Lease Terms (Binary)	1
Number of days on market	1
Rent-Free Period	1
Distance to Train	1
Year Built	1
Type of tenant/owner (Binary)	1
Net-Contract (Binary)	1

Amenities (Binary)	1
Average Rent	1
Maximum-contiguous space	1
Suburb (Binary)	1
0.5 mile to rail (suburb/CBD) (Binary)	1
Quarterly Return	1
Mean travel time (commute)	1
Population Density	1
Tax-Rate (property)	1
Residential	
Bathrooms	1
Bedrooms	1
Garages	1
Distressed Sale (Binary)	1
Pool (Binary)	1
Cooling System (Binary)	1

Sources: Chegut et al. (2013), Dermisi (2009), Eichholtz et al. (2010), Fuerst and McAllister (2011), Kok and Kahn (2012), Pivo and Fisher (2010), Wiley et al. (2010).

2.2.2 - Critique of Hedonic Studies

The studies reviewed above are part of a growing trend in academic literature studying the economic effects of green features and certifications. While they are an important starting point, much more varied research needs to be performed in order for us to fully understand what green buildings offer to the market-place and how they are appreciated. Firstly, there is a dearth of academic studies in Canada examining these questions. Up to now, much of the research has focussed upon engineering and technical costing models, and market-demand/consumer preference has received little academic attention. Secondly, hedonic regression-based models of the type reviewed only demonstrate "average" relationships. While this may be interesting to know from a policy perspective, from a valuation perspective, it is difficult to translate these correlations into actual investment and under-writing decisions. Thirdly, while the certification variable may serve as a good barometer of 'sustainability', modelling this variable does not perhaps say much about exactly which features are valued, as certification is the result of a combination of efforts, technologies, benefits, and conveniences. As such, in Canada, we are still largely in the dark as to what green features are actually valued and whether certification adds value to a home.

3.0 - METHODOLOGY: HEDONIC MODELS

The research question put forward in this study aims to determine, using statistically rigorous methods, whether green buildings capture higher market-valuations and (secondly) prices. With respect to the first part of our question (market-valuation), there are enough public data available that we can use regression analysis to investigate the question. Concerning prices, given the limited number of properties that have achieved green certification in Canada (see Introduction), and the lack of publicly available data on historical sale prices, we must resort to other methods. Thus, we have chosen a paired analysis approach to answer the second part of our research question. In this chapter, we will be discussing the green characteristics of the certifications we have chosen to model, the hedonic-pricing theoretical framework, the paired-analysis, and the vacancy rate testing methods. We will also provide a description of the public-available data we used for carrying out our hedonic model and the basic transformations made to them, however, full model-specification will be described in more detail in Chapter.4, due to the diagnostic tests involved in such a process.

3.1 - A description of the 'green' characteristics of LEED and BOMA-Best properties

One of the challenges involved in studying and developing the idea of the 'green' building is that it is somewhat of a vague concept. Indeed, perhaps one of the few things that we can agree on is that 'green' means different things to different people (UBC, 2010). A good synopsis of as to why some confusion may occur when we speak of green buildings comes from the University of British Columbia's Sauder School of Business' course-book, *Getting to Green: Energy Efficient and Sustainable Housing*. In it, the authors state, "for most, green implies environmentally friendly. For others, green is inter-changeable with sustainable, high performance, or energy efficient" (UBC, 2010, Pg. 1.2). It is not our task in this study to define what constitutes sustainability in the real-estate sphere. Rather, it is incumbent upon us to justify the green certifications we have used as our proxy for 'greenness'. In our study, for the residential sector, we have used the LEED certification for homes as our standard signifying the existence of green features.

The selection of these two standards rested upon considerations related to popularity (in terms of use-Introduction chapter), methodological rigor, and the public availability, ease, and cost of the information that we could obtain with respect to the individual properties certified. First, we will provide a description of these certification schemes.

Green Characteristics of LEED homes

As we can see from Table-3.1 below, it is one of the most comprehensive certification schemes for residential properties in the country. Furthermore, it is the only certification which has publicly-accessible data-bases available for perusal.[10] We investigated the other certifications that are listed in the table, however, the same public and cost-free access could not be obtained.

When it comes to residential properties, given the plethora of certification schemes that builders/developers and purchasers can choose from, it is prudent to first develop an understanding of the kinds of green labelling schemes available in the market and the features and variables they each try to address and/or promote. As we can see (Table-3.1), there is a wide range of certification schemes available throughout Canada, some restricted to only certain provinces. The Built Green and LEED for Homes certifications provide the most comprehensive coverage for residential properties, tackling the largest number of sustainability-related variables (UBC, 2010). In the case of the latter, the builder must meet a checklist of 'green' criteria in order to receive one of four levels of certification (Certified/Bronze/Silver/Gold).

[10] LEED certified properties are listed in the Canada Green Buildings Council website, complete with address, project name, type and level of certification, and the date certified. A listing of Canadian properties certified by the US Green Buildings Council (USGBC) is also provided by the website of the organisation, through their project search-engine.

Table 3.1 Comparison of Certification Schemes - Residential							
Category of "Green"	**Goal**	**Ener-guide**	**Energy-Star (Sask/ON)**	**Power Smart (BC/Manitoba)**	**R-2000**	**Built Green**	**LEED for Homes**
Ener-guide Energy Efficiency	Low electric bill	x	x	x	x	x	x
Appliances/lights	Low electric bill		x	x		x	x
Indoor air quality	No toxins				x	x	x
Environmental Impact	Reduce, Reuse, Recycle				x	x	x
Resource use/waste	Regional, renewable, rated materials					x	x
Sustainable sites	Less irrigation, less pavement					x	x
Location and linkages	Bus, walk, shop local					x	x
Education and awareness	Signs, logos, marketing					x	x

Source : UBC, 2010.

In our study, we chose to utilise the LEED certification because it is the most comprehensive (as shown above), and it is the only residential certification which allows users to access freely available public information to be posted on the CaGBC website regarding basic project details such as project name, project address (crucial for obtaining valuation information), certification level and type, and the date the project received certification. We used Canadian properties certified by the USGBC to help increase our sample size, as a larger sample in regression analysis (and statistics) is generally preferred.

Following the example of the USGBC, the CaGBC brought the LEED certification into Canada. Depending on how the homes are constructed, the properties upon the attainment of a minimum amount of points are given the label 'certified' (45-59 points), or receive higher levels of certification such as silver (60-74 points), gold (75-89), or platinum (90-136) (CaGBC, 2013).

To add more clarity to the description above, according to course manuals prepared by the CaGBC (2013), the LEED Canada for Homes Rating System measures the overall performance of a home in eight major categories, which are described below in Table 3.2. While the LEED certification may have some short-comings[11], given the range of green factors and features that it

[11] Denzer and Hedges (2011) argue based on their study of the Xanterra houses near Yellowstone National Park that the (self-reported) reporting procedure used by LEED did not accurately reflect the architectural design and construction of these houses. They argue that other studies have shown that a major problem with the LEED certification is its failure to account for the building's performance over the projected life of the building. In the case of the Xanterra properties they examined, this was confirmed as the lifespan of the concrete was not adequately considered by the rating process. Furthermore, Orr (2014) reviewed some of the criticisms which have been launched against LEED. In addition to uncertainty with respect to actual energy savings, other issues include the complicated and costly nature of certification, emphasis on the "manipulation" of points to gain certification rather

tries to address and incorporate, we feel comfortable using this certification to indicate the existence of a green residential property in our model.

Table 3.2 LEED for Homes sustainability categories	
Innovation and Design process	Special design methods, unique regional credits, going beyond rating system, exemplary performance
Location and Linkages	Homes built in socially and environmentally responsible ways in relation to community
Sustainable Sites	Use of the entire property
Water Efficiency	Water efficiency, both indoor and outdoor
Energy and Atmosphere	Energy efficiency, particularly in building envelope and heating/cooling
Materials and Resources	Efficient use of environmentally friendly materials, minimal waste during construction
Indoor Environmental Quality	Reduction of exposure to pollutants
Awareness and Education	Education of the home-owner, tenant, and building manager about LEED features

Source: CaGBC, 2013.

If we break down the points structure a bit further (Table-3.3) we can see which green features may earn an applicant the largest number of points (an indication of which green features figure prominently in LEED certification). We can see below that the use of the site in a sustainable manner, energy reduction/pollution, and indoor air quality improvements allow a client to gain the largest amounts of points.

Table3.3 LEED points break-down		
	Minimum points requirement	Maximum points available
Innovation and Design process	0	11
Location and Linkages	0	10
Sustainable Sites	5	22
Water Efficiency	3	15
Energy and Atmosphere	0	38
Materials and Resources	2	16
Indoor Environmental Quality	6	21
Awareness and Education	0	3
Total	16	136

Source: CaGBC, 2013.

Green characteristics of BOMA BEST commercial properties

According to the University of British Columbia's Commercial Green Building (2010) course manual, there exist only two certification programs for commercial properties in Canada, LEED and the BOMA BEST ratings (UBC, 2010). While LEED is designed for both new and existing

than focussing upon the best environmental outcomes, lack of appropriate weighing of points and how they are achieved.

buildings, the BOMA BEST certification is designed for helping with the re-fitting of the existing building stock.

In order to carry out our analysis of the commercial sector, we examined both certification schemes but decided to limit the analysis to properties certified by the BOMA BEST program due to the limited number of properties which have achieved LEED certification status (see Pg. 52-53). Thus, we will now proceed to explain the green features associated with the BOMA BEST certification.

The BOMA BEST certification is administered by the Building Owners and Managers Association of Canada. The certification aims to address six key areas of environmental concern:

- Energy
- Water
- Waste and Site
- Emissions and Effluents
- Indoor Environment
- Environmental Management System

Those wishing to gain certification for their property must fill out an online questionnaire with respect to the key environmental variables outlined above. Following this, an on-site verification must be conducted by a third party to ensure the validity of the responses. The onsite verification is essential and must occur prior to the granting of the certification (BOMA, 2013). Under the scheme, there are four certification levels available, they are described in Table 3.4 below:

Table 3.4 BOMA BEST LEVELS

BOMA BEST LEVEL 1	Indicates that a building has met all the 14 BEST practices
BOMA BEST LEVEL 2	Indicates the building has met the 14 BEST practices, and has achieved a score of 70 to 79% on the BOMA BEST Assessment Module specific to the building type
BOMA BEST LEVEL 3	Indicates the building has met the 14 BEST practices, and has achieved a score of 80 to 89% on the BOMA BEST Assessment Module specific to the building type
BOMA BEST LEVEL 4	Indicates the building has met the 14 BEST practices, and has achieved a score of 90% or higher on BOMA BEST Assessment Module specific to the building type

Source: BOMA BEST, 2014.

We have outlined 6 key areas for environmental sustainability above, which in turn can be divided into 14 questions (or best-practices) (see Table 3.5) which certification clients must answer. Those are described below:

Table 3.5 BOMA BEST Questionnaire

	Question 1-14	Required policies and practices
Energy	Energy assessment in the past 3 years?	Minimum of an ASHRAE Level 1 audit
	Energy reduction plan in place?	Plan must document measures to improve efficiency
	Maintenance plan for HVAC systems?	Plan must include review/corrective actions on a regular basis
Water	Policy to minimize water use, conservation?	Plan: commitment, establish goals, and strategies
	Water assessment in the last three years?	Assessment: water billing analysis, list of conservation options
Waste (reduction) and Site	Waste diversion program? Recycling?	Active recycling/reuse program
	Policy to minimise construction waste?	Source separation and recycling; recycling of cardboard, metals
Emissions and Effluents	Management plan for Ozone depletion?	Inventory of refrigerants, reports of loss/leaks, training, testing
	Phase-out of ozone-depleting refrigerants?	Implementation plan to phase-out ozone depleting refrigerants
	Hazardous building materials survey?	Inventory of hazardous materials present at the facility
	Hazardous products management plan?	Plan outlining reception of controlled products, use, disposal
Indoor Environment	Plan in place for addressing air quality issues?	Plan for addressing tenant concerns, incident log, remedial steps
Environmental Management System	Policy for selection of building materials?	Policy for selecting low impact building materials (recycled)
	Communications plan for tenants?	Communication plan re: environmental practices with tenants

Source: BOMA BEST, 2014.

Thus, given that the BOMA BEST certification targets a generally wide array of environmental factors/concerns for existing buildings and has a publicly-available listing of projects, we will be using it as our green standard for the commercial sector.

3.2 - Hedonic Pricing: Theoretical Background

The literature review section has discussed at length as to how the academic community has attempted to answer the question of whether there is a green premium. For this section, we will proceed to explain and justify the regression modelling techniques used for both the commercial and residential sections. We will provide a more in-depth explanation as to what regression modelling tries to achieve, and how it makes sense given our research question. Secondly, we will outline the sources of the data and the methods used to transform them.

Hanley and Barbier (2009, Pg.98) argue that, "hedonic pricing (HP) seeks to find the relationships between the levels of environmental quality (such as noise levels or air pollution levels) and the prices of the marketed goods....HP can also be used to investigate the 'green' premium attached to products".

Furthermore, using an example which coincidentally incorporates the value of homes, they illustrate that the price of any given house (*hi*) is a function of the characteristics of that house (**Zi**). Thus, the relationship can be defined as:

$$P(hi) = f(\boldsymbol{Zi})$$

Therefore, according to this theoretical framework, discovering the relationship between a 1-unit or "marginal" change in any characteristic and the price of a home, leads us to discover the 'implicit' price (or value) of that characteristic. Naturally, then the estimation of this implicit price allows us to understand the marginal willingness-to-pay for that environmental characteristic (ibid, Pg. 99).

There are two steps involved in the 'hedonic' modelling exercise. First, one must decide which environmental characteristic(s) is of interest. Secondly, once we have decided upon the environmental characteristic(s) of interest, we must estimate a "hedonic price function" which essentially summarizes both our objective and the statistical model to be used. Hanley and Barbier propose a simple form for such an equation:

$$\text{(Equation-1) } P(hi) = p(Si, Nj, Qk) + \mu$$

Where P(hi) is the price of house (i), Si are the site characteristics associated with house (i), Nj are the neighborhood characteristics of that neighborhood, and Qk represents the environmental variables.

To sum up, estimating a modified form of Equation-1 will allow us to learn whether there is a statistically significant and positive relationship between the environmental characteristics and the price of the home. Or, in our case, test whether there is a positive and statistically significant relationship between market-valuations (assessed values) and green environmental characteristics (i.e., certification)[12].

[12] NOTE: As the Literature Review chapter (Pg.36) indicates, regression modelling has often been employed to estimate statistically the hedonic price function, and derive the influence of each individual building characteristic.

In our case, we are not privy to private information about a home that would allow us to model 'individual' environmental characteristics. Rather, we will be using information that is publicly available, i.e., the nature and type of the green certification of individual homes and commercial properties.

3.3 - Residential: Hedonic Model - Data Sources and Adjustments

Using the search engine of the CaGBC, as of July 31st (2013), we were able to find 105 properties around the country which had been certified under the LEED for Homes program certified properties in the other provinces were limited[13]. We considered the possibility of adding Alberta to the list of provinces studied, however, market-valuation figures are provided locally in the province, and home features are not described in valuation reports (as is the case in Ontario and British Columbia). From the initial stages we concentrated our search upon Ontario, Quebec, and British Columbia.

As mentioned before, the CaGBC (2014) website provides basic information with respect to projects such as the name, address, the dates of registration and certification, the project size (square footage), and the level achieved. It should be noted that as of July 2013, a further 257 properties were certified in Canada by the USGBC. However, a listing of the addresses of those properties could not be obtained despite repeated inquiries (as the website listing for those 'separate' properties did not provide the necessary information).

Ontario

From the original sample mentioned above (of 105), 25 properties were certified by the CaGBC in Ontario. In October of 2013, the CaGBC revamped their website and updated the list of certified properties. This added to the number of potential properties available and the sample in Ontario increased to 43 properties. Furthermore, at the same time, a list of 23 properties was obtained directly from the USGBC (2013) website's search engine (since Canadian properties are sometimes certified by the USGBC and listed on its website)[14]. From this, only 6 properties were chosen since there were numerous repetitions in the pool from the same street (the choice was

[13] For instance, during the initial search the number of LEED certified homes were 13 in Manitoba, 6 in Alberta, none in Saskatchewan, 1 in New Brunswick, 5 in Nova Scotia, 1 in Prince Edward Island, and 2 in Newfoundland-Labrador.
[14] http://www.usgbc.org/projects

random). Indeed, out of this list one street contained 9 certified properties, another 8, and one had 2 certified properties. The first two streets contained properties which were townhouses and identical. Hence, due to cost-considerations[15] we chose only 1 property from each of these streets, the same was done for the third street with two certified properties (in all cases, the choice was made randomly)[16]. Out of the 49 (sub-total) properties, three were confidential projects and no addresses were provided. Thus, the final potential list of properties was 46.

The Municipal Property Assessment Corporation (MPAC) is able to provide various levels of property data depending on how much cost the client is able to incur. The highest levels of detail are provided by the **'Residential Detail Report (Level 2)'**. This report is available for an individual property if the address is provided. The report provides the current assessed value, the type of home, total area (square-feet), year built, number of storeys, bedrooms, and bathrooms, condition of the basement, the type of hydro, water, and sanitary system. Other important information includes the last valid sale date and the amount of the sale. In addition to this, the features of the homes are listed such as property type, year built, floor area, number of bedrooms, bathrooms and frontage area. The variables available are shown below:

Table 3.6 MPAC Data (Residential)

Subject Property	Comparables
Subject real-time market valuation (Sept 2013)	Subject real-time market valuation (Sept 2013)
Property Type	Property Type
Year Built	Year Built
Total floor area (above grade, individual floors)	Total floor area (above grade0
Basement finished area	Basement finished area
Number of bedrooms	Number of bedrooms
Number of Full Bathrooms	Number of Full Bathrooms
Number of Half Bathrooms	Number of Half Bathrooms
Frontage	Frontage
Depth	Depth
Site Area	Site Area
Assessed Value (as of Jan1, 2012)	Comparable Sale Date and Price
Legal Description	
Utilities	
Last valid sale date and amount	

Source: MPAC, 2013.

[15] MPAC data is not available free of charge.

[16] It should be noted that out of the 6, only 4 were eventually included in the model since valuation information could not be obtained for two of them. And all 4 were from different streets.

When we entered these 46 properties into MPAC's search engine, the necessary information could not be obtained for 21 of them. The reasons include valuations not being available for those properties, or that the comparables could not be generated by the automated-system (an essential ingredient in the research). Thus, the final list of subject properties for Ontario was 25, with 62 comparables generated by the MPAC system from the same neighborhood with similar characteristics. In some cases, the data-base returned only one or two comparables for a subject property. The MPAC system in Ontario generated one comparable property for four subject properties, and two comparables for five subject properties.

Real-time market-valuation data (from MPAC) were obtained for all properties over the period September 2013 to March, 2014. However, the valuations were 'adjusted' to November 2013. This is due to the fact that the largest number of valuations were obtained from that time-period. These adjustments were made using the percentage changes in average sale prices and the price indices of particular neighborhoods and cities. For the Toronto area, the adjustments were made on a neighborhood basis using the benchmark price and price indices provided by the Toronto Real-estate Board (TREB, 2014) for detached homes. For properties outside of Toronto, we used one of the flagship publications of the Canada Mortgage Housing Corporation (CMHC, 2013) called Housing Info Monthly, calculating the percentage changes in the average selling prices of absorbed properties (detached/semi-detached) over time. Lastly, for Milton, we used the average sale price of detached homes from the Milton Real-estate Board (2014). It should be noted that in ALL cases, the valuations for subject (green) properties were obtained post-certification[17].

British Columbia

For British Columbia, out of the original sample of 105 subject green properties, 10 were based in that province. In October 2013, that sample increased to 16 properties following the CaGBC upgrade. These 16 properties were searched through the LANDCOR (a real-estate research firm) search engine. The descriptions and valuations of 11 properties and their comparables were obtained through this method. Similar to the MPAC system in Ontario, Landcor in British

[17] NOTE: Throughout our study, valuation figures have been adjusted to specific points in time for both the commercial and residential models. It must be understood that market-valuations and selling prices may not necessarily correlate. Selling prices may be subject to fluctuations that are not always entirely related to economic and market dynamics and may partly reflect human sentiments. However, selling prices (or rents) serve as at least reliable benchmarks upon which market-valuations can be adjusted, as there is a risk of using valuations that do not reflect the actual market conditions being studied if unadjusted valuations are used.

Columbia provides comparable data for properties in the province. The Property Valuator, available for purchase, provides a listing of the variables shown below.

Table 3.7 Landcor data (residential)	
Subject Property	**Comparables**
Year built	Address (and neighborhood)
Finished Area	Sales price and Date
Fireplace	Assessment (land and building - **as of July 1, 2012/13)**
Stories	Age, Size
Deck (area)	Bedrooms, Bathrooms
Pool	Parking
Garage (type)	Living Area
Assessment history (2010-2013)	Renovations (effective age)
Sales History and Type	Lot-size
Neighborhood Sales averages	Garage type
Property type	
Lot-size	
Bedrooms	
Bathrooms (number and type)	
Total Living Area	
Basement (area)	

Source: Landcor, 2014.

BC Assessment provides its valuation figures for properties in that province every year on the first day of July. However, in our modelling exercise, the date we have used to adjust our dependent variable (market-valuation) towards is November 2013. This is due to the fact that once Ontario (the largest sample base) is brought into the picture the valuation timing changes. All of Ontario's 'real-time' valuations were obtained from Ontario's Municipal Property Assessment Corporation during the fall of 2013 and a small number from spring 2014 (March/April), and the largest number from the fall were obtained during November 2013. Thus, if we wanted to do the 'least' number of adjustments to the overall data-set, then using November 2013 as the base valuation date offered the most prudent route. Therefore, in the case of the properties in the Greater Vancouver/Victoria area, where all our sample properties are from, the (BC Assessment) market-valuations were adjusted forward from July 1st, 2013 to November 2013.

This transformation was done on a neighborhood-by-neighborhood basis, using data from the Real-estate Board of Greater Vancouver (2014) (adjustment required the use of the Home Price Index, by property-type). The percentage movement of the index over the 4-month period provided us with the adjustment factor to be used. For the properties in Nanaimo, the percentage

movement in Canada Mortgage Housing Corporation's (CMHC, 2013) Average Sale price of Absorbed Units (Detached/Semi-detached) was used for adjustment[18]. Again, as in the case of Ontario, all the valuations used and adjusted are post-certification for all the subject properties.

Quebec

In the original sample of 105 LEED properties, there were 37 properties certified in Quebec. After the October 2013 upgrade, the sample almost doubled to 72 properties listed. For the properties in Quebec, publicly available municipal valuation data were available for only Montreal, Gatineau, and Sherbrooke.

However, there were several larger issues with the Quebec properties. First, the data purchased from the real-estate research agency in Quebec often did not provide complete and reliable information with respect to the properties in our sample. For instance, often basic data such as property size, stories, and the number of bedrooms and bathrooms were missing. Also, when 'official' valuation figures were compared to the figures listed by the JLR (real-estate) data-base[19], there was often a discrepancy. Secondly, the most problematic issue was the fact that the vast majority (almost all) of the properties obtained in Quebec were much older (some from the 1800s) and were townhouses, condominiums, and apartments located in central Montreal. This was problematic due to the fact that the vast majority of the properties in our overall sample were single-detached homes. While this could be controlled for in regression modelling, it presents a risk. Plus, it is not always clear from the basic CaGBC listing how much of a building (which part) was certified, thus, the reliability of the valuation figure could be called into doubt. For these reasons, it was felt that it is best to leave the Quebec properties out of the model in this study.

To summarize, the valuation data chosen for our residential hedonic model were adjusted to represent value as of November, 2013. We limited our analysis to Ontario and British Columbia due to data unavailability. As such, this analysis should not be considered as representative of real-estate markets nation-wide.

[18] CMHC, Housing-Info Monthly.
[19] JLR is a real-estate research service with products similar to the ones provided by Landcor and MPAC.

Furthermore, this data-set represents the (mainly urban) dynamics in just two provinces. Hence, the conclusions we draw can at best be a (limited) representation of the urban real-estate markets and the valuation industry/methods in Ontario and British Columbia for the residential sector. However, given the small sample-size and the diversity of locales included in the study, we still need to be cautious about generalising these results even within the context of those two provinces. Our commercial analysis is broader (a larger sample comprising the four main commercial office markets in the country) and is perhaps more representative. However, compared to other hedonic studies, our sample size is much smaller, and so we still need to be tempered in our conclusions.

3.4- Commercial: Hedonic Model- Data Sources and Adjustments

There are two certifications available for commercial properties in Canada, LEED and BOMA BEST. Just as we did for the residential sector, we examined the LEED certification first. As of mid-December 2013, there were 143 LEED commercial properties listed in the CaGBC public search engine. Broken down by city, there were 35 in Calgary, 64 in Toronto, 9 in Montreal, and 35 in the greater Vancouver/Victoria area.

Although this was a decent-sized sample of subject properties, there were some major issues associated with using the LEED designation. First, it was apparent when we looked at the project descriptions that many of the projects covered only a part of the building (sometimes only a floor or a single suite). For example, in some instances, there was a discrepancy between the project square-footage as listed by the CaGBC and the building-size as listed by the Altus-Insite (2014) website, or information provided by the website of the building management company. In some instances, the project description provided by the CaGBC would list the suite number associated with the project.

Furthermore, with respect to LEED, there were several certifications within the 'commercial' category. These included categories such as LEED for 'commercial interiors', 'new construction and development', 'core and shell', and 'existing building: operations and maintenance'. Lastly, there are certifications available for both existing and new construction. Accounting for all of these factors in the modelling exercise would have likely led to inconsistencies and inaccuracies given the limited sample available. Also, given that detailed project descriptions are also not available without contacting project/building managers, developing appropriate indicator

variables to control for the wide range of data for each property would have been a highly complex task. Therefore, a decision was made early to focus upon the BOMA BEST certification which provides a public data-base of projects (BOMA-BEST, 2014), and their certification is based upon whole-building performance for existing buildings (a consistent and easier standard for modelling). We searched for projects in the four key business centers in Canada, they are Toronto, Montreal, Calgary, and Vancouver. This is illustrated in:

Table 3.8 Biggest Commercial Office Markets (sq.ft)

Downtown Office	Existing Inventory (sq. Ft) June 30, 2014	Suburban Office	Existing Inventory (sq. Ft) June 30, 2014
Toronto	70,514,344	Toronto	67,879,191
Montreal	49,610,579	Vancouver	29,985,814
Calgary	40,447,480	Calgary	25,818,920
Vancouver	24,474,251	Montreal	25,664,903
Edmonton	17,140,407	Ottawa	21,293,374
Ottawa	15,995,156	Edmonton	9,544,323
Winnipeg	11,944,204	Waterloo Region	7,379,966

Source: Colliers International, 2014.

Also, assessment data for Montreal (2014), Calgary (2014), and Vancouver (2014) can be found free of charge through provincial and regional bodies. The official valuation dates (as used by the appraisal agencies) for these cities are provided below:

Table 3.9 Valuation Dates by City

Montreal (Ville de Montreal)	July 1, 2012
Ontario (MPAC)	January 1, 2012
Calgary (City of Calgary)	July 1, 2013
Vancouver (BC Assessment)	July 1, 2012

In the case of Calgary, even though valuations are performed as of the same July 1st date every year, by the time we had decided to obtain data for Calgary, the July 1, 2012 value was no longer available, and the agency could not provide us with the earlier valuation information. Hence, this necessitated an adjustment to the Calgary valuation.

When we consider the table above, clearly the most prudent approach would be to model valuation as of July 1, 2012 (necessitating the least number of adjustments). Therefore, we

needed to move Ontario forward by six months, and Calgary back by one year[20], using market-based data. We could have used July 1, 2013 as the valuation date, however, that would have been cost-prohibitive in the case of Ontario as 'real-time valuation' can only be purchased.

In both cases, after perusing the reports of several real-estate management and research companies, we decided upon the 'average gross asking rent' in both jurisdictions as our metric for measuring how the market has transformed. These data are provided by the real-estate agency Jones Lasalle Lang (2014) and are differentiated according to office district and building class, the most completely detailed of all the sources studied. Therefore, the percentage change in average gross asking rent over two quarters (in the case of Toronto) and four quarters (in the case of Calgary) was the basis for adjusting the market-valuation variable. Gross asking-rent was provided consistently, was less variable than vacancy-rates, and historical selling prices were not available.

Furthermore, as before, all valuations used (for subject 'green' properties) would have to be post-certification by BOMA. This implied that, to be included, the Toronto subject properties must have attained certification before January 2012, Calgary properties before July 2013 (although all were certified before July 2012 in our sample), Montreal properties before July 2012, and Vancouver properties before July 2012.

Commercial Properties: Comparables Generation and Finalisation

When we were modelling the residential properties, comparables were generated for us automatically by the valuation agencies MPAC (Ontario) and Landcor (BC). However, this service was not available in the case of the commercial properties for any city. Hence, we needed to generate the comparables ourselves using publicly available tools. The first step was to search for comparable properties on the same or nearby streets close to where the subject property was located. This was facilitated by the real-estate search engine Altus-Insite (2014).

Our procedure entailed inputting the street name(s) into the search engine. The Altus-Insite tool in turn provided a list of commercial buildings on that street with basic information such as building name, class, footage, age, certification status, parking ratio, and the vacancy rate. While

[20] One can recognize this as a limitation of the study, given the changes which can occur to a market during the course of a year.

we strove to find comparables that were approximately the same size, in a number of cases this was not possible due to a scarcity of non-green properties of approximately the same size in that particular district/neighborhood[21]. However, multi-variable regression methods are designed to control for each variable and so differences in the size of a subject and comparable property will not affect our evaluation of the 'independent' effect' of certification upon market-value. Lastly, we made sure that the comparables were not certified (neither BOMA BEST nor LEED as of July 1, 2012), and were not repeated again in our sample (they were not comparables for any other subject property).

In order to obtain further information about the amenities contained in each building, we searched through the building's real-estate management company's website. If there arose any conflict with the information between these 'primary' sources and the Altus-Insite website, then the management company's information was given priority[22]. Also, it was essential that each building was solely for commercial use (no residential units). This was confirmed by checking the website information provided by the building's management company.

[21] In such cases, the primary criteria that were used to choose the comparables were factors such as Class of building, location (Office District), and the level of information available on that property. Given that 'close' matches were not always possible due to the type of neighborhood, and the type and number of properties available for analysis on the same street (neighborhood), the incorporation of indicator variables into the regression modelling was implemented to control for those factors.

[22] Such discrepancies occurred in the cases of approximately one-third to fifty-percent of the commercial properties we studied.

3.5- Regression Analysis: Basic Steps

In regression analysis, it is standard practice to utilise a linear ordinary least squares (OLS) model to fit the data first. This is because it is the easiest model to interpret and compute[23]. However, before we attempt to fit a linear model to test the effects of green features on buildings, we must be clear about the four basic assumptions that a linear model must meet from a statistical point of view in order to be considered viable. These are the assumptions we will be testing for both the residential and commercial models. They are:

1- Normal distribution (pre-regression)

A sound linear regression model recommends that the dependent variable is normally distributed. If the dependent variable is non-normally distributed, it is a more difficult task for the model to fit a linear-relationship that is free of issues such as hetero-skedasticity and 'abnormality' of the error terms. This can arise due to dependent variable having too many variables located at the extreme end of the distribution (De Veaux et al., 2012). We will measure normal distribution through the use of the Shapiro-Wilk test for normal data in this study[24].

2 - Relationships are linear (Pre-regression)

It is crucial to have underlying linear relationships between the explanatory variables and the dependent variable. Otherwise, OLS is not appropriate and a non-linear estimation method may need to be found. A preliminary test for this is to create scatter-grams between the dependent variable and each of the explanatory variables. As an added step, we will also include in our study a post-regression graphical test to confirm that the relationships are linear. Furthermore, prior to regression, we will use the Pearson correlation tests to determine whether there are linear relationships between the continuous explanatory variables and the dependent variable. The use of chi-square tests will be employed to test for relationships amongst the categorical variables. Lastly, checking the normality of the residuals (the variation in the dependent-variable that is not explained by the model) is also another method for assessing the linearity of our relationships and the appropriateness of using a linear model. We will do this as well post-regression modelling (De Veaux et al., 2012).

[23] And is the model most utilised in the hedonic studies we reviewed.
[24] In our case, robust-regression techniques will be utilised which do not assume normality of the dependent variable.

3- Homo-skedasticity (Post-regression)

Another requirement of OLS is that the variance of the errors around the regression line must be the same for all the explanatory variables, an indication of the 'strength' of the slope co-efficient. Again, this can only be checked after the linear regression line is fitted to the data. Generally, the test to assess for homo-skedasticity is a graphical plot of the residuals versus the predicted-values of the dependent variable (De Veaux et al., 2012), followed by perhaps a more formal hetero-skedasticity test. However, in our case we will be using 'robust' regression techniques made available by the STATA statistical package which will not assume homo-skedasticity while running our regression.

4- Independent errors or auto-correlation (Post-regression)

The errors must be independent, with no correlation amongst them. The errors are simply 'outside' factors that are not included in the regression model. If there is a relationship amongst them, then that could be an indication that important variables and relationships are being left outside of the model which could potentially add to the explanatory power of our model (De Veaux et al., 2012). In order to test for this, we will plot the residuals versus the predicted values of the dependent variables. The absence of auto-correlation can be confirmed if there are no discernible bends or patterns in the relationship graphed.

5- Multic-Collinearity (Post-regression)

In OLS modelling, it is important that there be no linear-relationships present between the explanatory variables. The presence of this phenomenon makes it more difficult to ascertain the 'independent' effect of each of the explanatory variables (De Veaux et al., 2012). We will test for multi-collinearity post-regression by calculating the 'variance-inflation factor', a command available in STATA.

4.0 - RESULTS: HEDONIC MODELS (RESIDENTIAL AND COMMERCIAL)

4.1 - Hedonic Model: Residential

4.1.1- Descriptive Statistics: Residential

The following is a description of the variables used for carrying out the residential regression model.

Evaluation-Adjusted

The evaluation variable utilised is an estimate of the market-value (in Canadian dollars) of each home 'as of' November 2013. As mentioned in the methodology chapter earlier, some adjustments had to be made for properties in both British Columbia and Ontario to bring the valuations to this specific date. Below is a description of this variable:

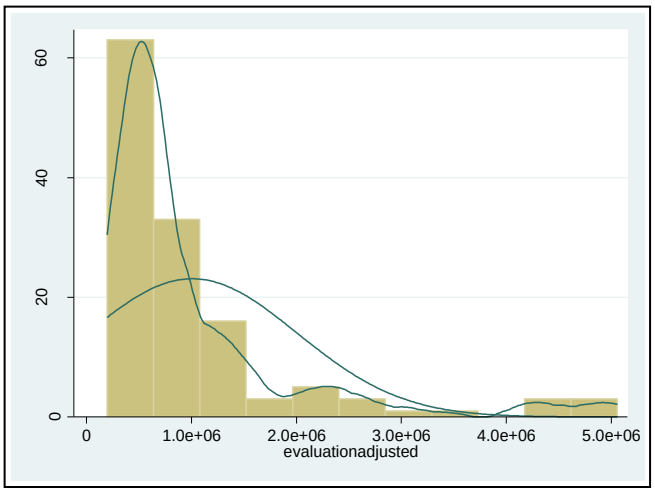
Table 4.1 - Evaluation-Adjusted

Percentiles	Smallest		
1% 201368	196000		
5% 225000	201368		
10% 374000	208310	**Obs**	131
25% 462069	217458	**Sum of Wgt.**	131
50% 662000		**Mean**	1007636
	Largest	**Std. Dev.**	999777.5
75% 1152447	4412397		
90% 2250000	4839403	**Variance**	1.00e+12
95% 3311056	4868650	**Skewness**	2.44289
99% 4868650	5056806	**Kurtosis**	8.852442

As can be seen above, the adjusted market-valuations for residential properties have a mean of just over $1 million, with the 50th percentile at over $660,000. While those properties at the very top (or 99th percentile) are valued at almost $5 million, at the lower end (5-1 percentile), they are valued at just over $200,000. When we plot the histogram of the variable, as can be seen, the distribution is indeed positively skewed. The less steep (and bell-shaped) curve indicates how it would have looked had it been normally distributed. When we compare the distribution of the

valuation variable (the positively skewed line) to the smoother 'normal' line, we can see that we are well off the 'normal' path (Fig-4.1).

Figure 4.1 - Histogram - Evaluation-Adjusted



An oft-used (and non-graphical) technique for measuring the normality of a variable is the Shapiro-Wilk test (STATA, 2014). We can use this test to evaluate the normality of our dependent variable, the hypothesis that the distribution is normal (null hypothesis). The statistic we want to focus on is the p-value. If the p-value is greater than the chosen level of significance (or alpha) then the distribution can be considered normal. A reasonable standard for the alpha is the conventional 5% level of significance, which will be used throughout the course of this essay.

When we perform the Shapiro-Wilk test for normality on evaluation-adjusted, the result reinforces the point made above. In this case, the p-value of 0.0000 (Prob> z) is much less than the 5% level of significance, so we know that this is a non-normally distributed variable (Table-4.2).

Table 4.2 - Test for Normality - Evaluation-Adjusted

Shapiro-Wilk W test	for normal	data		
Variable	Obs W	V	z	Prob>z
evaluation~d	131 0.67075	34.128	7.946	0.00000

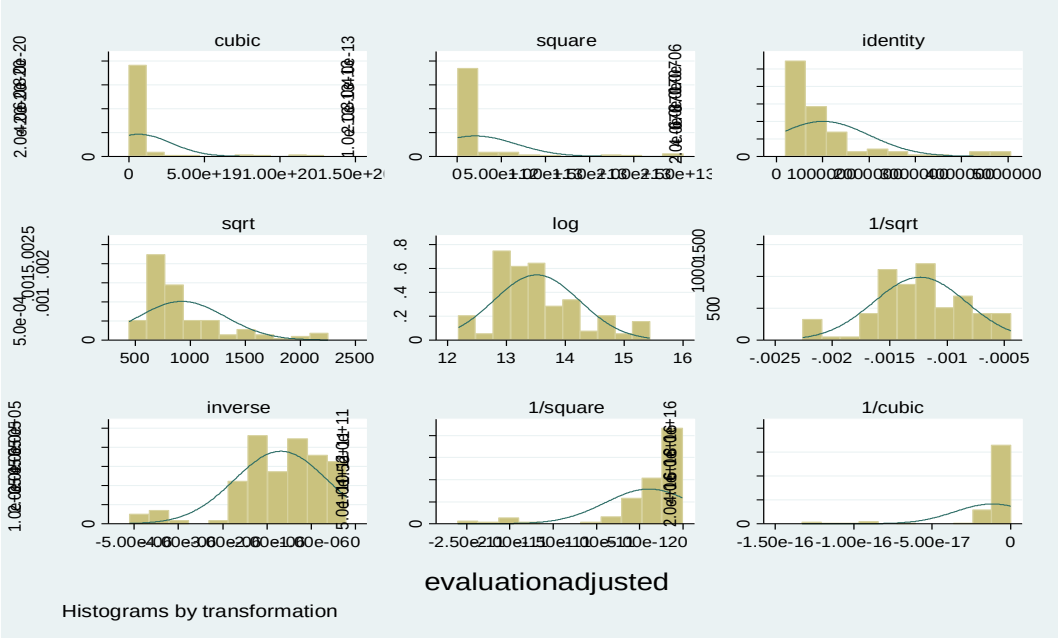
Fortunately, there are various techniques available to us for transforming the dependent variable to one that is normally distributed (or one that closely resembles normal distribution). To help us choose the transformation method, STATA is able to perform a 'ladder' test. It provides a convenient tabular and visual method for assessing the potential of each transformation method.

We can see from Table-4.3 and Figure-4.2 below that the inverse of the square-root method holds the greatest promise, with the lowest chi-square statistic (STATA, 2014).

Table 4.3 - Ladder Test - Evaluation -Adjusted

Transformation	formula	chi2(2)	P(chi2)
cubic	evalua~d^3	.	0
square	evalua~d^2	.	0
identity	evalua~d	59.19	0
square root	sqrt(evalua~d)	35.19	0
log	log(evalua~d)	10.39	0.006
1/(square root)	1/sqrt(evalua~d)	0.76	0.683
inverse	1/evalua~d	22.44	0
1/square	1/(evalua~d^2)	66.25	0
1/cubic	1/(evalua~d^3)	.	0

Figure 4.2 Ladder Test - Evaluation-Adjusted



As a test the inverse of the square-root of market-valuation was regressed upon city-type, property-type, logfloorarea, certification, basement, and sqrt-age. The regression co-efficients for large-city, detached properties, floor area, and basement were all negative and statistically significant. Also, the certification variable was not significant[25].

However, the log-linear model (using the logarithm of evaluation as the dependent variable) yielded the same answer to our research question and the explanatory power of the models were similar. Given that the log-linear model has a simpler interpretation (with respect to the co-efficients), we have chosen to utilise the logarithm of market-valuation as the dependent variable[26].

However, the log-transformation still does not produce a transformed variable that is normal. In our case, the p-value of 0.00002 is much lesser than the 5% (0.05) level of significance. Therefore, our variable, log-evaluation does not satisfy the normality assumption (Table-4.4).

Table 4.4 - Test for Normality - Log-Evaluation

Variable	Obs	W	V	z	Prob>z
logevaluat~n	131	0.94066	6.151	4.089	0.00002

As a remedy, the STATA statistics package contains a functionality that is able to provide "robust" estimates which does not assume normality. It will produce the same regression estimates with the exception that the t-values (the significance of the individual variables) will be lower (Acock, 2012). The robust option also does not assume homo-skedasticity.

City type

Given that the size of the city can have an impact upon home prices and valuations, the variable 'City Type' was also included in the regression analysis. It was felt necessary to include this in our case given the diversity of locales in our sample and the differing socio-economic conditions this level of diversity might entail. Specifically, we have included properties which have come from a wide range of municipalities from both Ontario and British Columbia.

[25] Why we used log-floor area and square-root of age is explained in the descriptive-statistics of those variables, due to absence of normality.
[26] For a comparison of the results see the regression results of the negative-reciprocal square-root model in Annex 4.

If the property was from a rural area or township, then it received a code of '1'. Likewise, a small city (less than 100,000 population) received a code of '2', a medium-sized city (100,000-1,000,000 population) received a code of '3', and a large city (1,000,000 + population) would be considered a '4'[27]. The overall distribution of the data is shown in Table-4.5 below. As can be observed, while townships, small and medium-sized municipalities make up 40% of the sample, it's dominated by larger cities (mainly the cities of Toronto and Vancouver).

Table 4.5 - City-Type

City Type	Frequency	Percent	Cumulative
1	17	12.98	12.98
2	16	12.21	25.19
3	20	15.27	40.46
4	78	59.54	100.00
Total	131	100.00	

Area type

While controlling for city size is important, it is perhaps equally important to also control for the type of neighborhood the property is situated in. This becomes necessary as there are bound to be various 'sub-markets' within any municipality. While we have not found a residential hedonic model which contains, for example, a residential vs. suburban dummy variable, the studies of Jim and Chen (2007) and Liao and Wang (2012) do incorporate dummy variables indicating whether a property is located in the old (central) town in the former case, and the distance to the central business district in the latter. In order to carry out this division, properties were classed according to two main categories, suburban-rural (0)[28], and residential-city (1). As can be seen in Table-4.6 below, there is a fairly even split between homes located within the city-limits (56.5%) in residential neighborhoods, and homes located in suburban areas (neighboring municipalities) and rural ridings.

[27] NOTE: One should consider these at best an approximation, in the context of Canada, particularly with respect to the 'medium' category as it is a large range. However, given the small sample size they suffice.
[28] NOTE: Given the small sample size, the suburban and rural properties were combined for the sake of simplicity and efficiency. Also, suburban properties were categorised as such if they were located in areas outside of the boundaries of the 'principal' city, for example, the Greater Toronto Area.

Table 4.6 - Area-Type

Area	Type Freq.	Percent	Cum.
0	57	43.51	43.51
1	74	56.49	100.00
Total	131	100.00	

Age

Another variable of interest to our model is the age of the house (in years-as of 2014), which is likely taken into account by prospective buyers and does play a role in the appraisal process. Furthermore, given that this is a 'continuous' variable, must also examine its distribution, to check for normality conditions. The mean age for the homes in our sample is 14 years. The Shapiro-Wilk (Table-4.8) test for normality shows us that we can reject the hypothesis that the data is normally distributed (P-value < 0.05). However, we will see further on that that is not an issue in our case, and a post-regression graphical test will confirm this (Chapters 4.1.2, 4.1.3). Lastly, the ladder test in Table-4.9 shows that the square-root of age is the best transformation for deriving a more normal distribution (however, normality is still not achieved through this method, but linearity conditions were met- See Chapter 4.1.3). In our principal residential model the age variable was included in its untransformed state, see the aforementioned chapter for an explanation.

Table 4.7 - Age

Percentiles		**Smallest**		
1%	0	0		
5%	1	0		
10%	1	0	**Obs**	131
25%	3	0	**Sum of Wgt.**	131
50%	5		**Mean**	14.47328
		Largest	**Std. Dev.**	24.26404
75%	10	90		
90%	45	91	**Variance**	588.7435
95%	88	91	**Skewness**	2.330826
99%	91	91	**Kurtosis**	7.127964

Table 4.8 - Test for Normality - Age

Variable	Obs	W	V	z	Prob>z
age	131	0.57771	43.771	8.506	0.00000

Table 4.9 - Ladder Test - Age

Transformation	formula	chi2(2)	P(chi2)
cubic	age^3	72.09	0
square	age^2	66.81	0
identity	age	53.18	0
square root	sqrt(age)	33.46	0
log	log(age)	.	.
1/(square root)	1/sqrt(age)	.	.
inverse	1/age	.	.
1/square	1/(age^2)	.	.
1/cubic	1/(age^3)	.	.

Property Type

The valuation of homes can also vary according to property type. Therefore, a variable to take this into account this was also introduced. In the hedonic literature, a similar categorical coding scheme was introduced by Keskin (2008) to indicate whether a property was a detached home or an apartment (building). For our classification, townhomes were assigned a value of '1', semi-detached properties are '2', and detached (single-family) homes are '3'. As can be seen below (Table-4.10), the vast majority of the properties which were analysed were single family homes making up almost 85% of the homes.

Table 4.10 - Property-Type

Property Type	Freq.	Percent	Cum.
1	12	9.16	9.16
2	8	6.11	15.27
3	111	84.73	100.00
Total	131	100.00	

Floor Area

The size of the home (in square feet) is perhaps the most important factor determining the value or price of a home. When we look at the summary statistics below (Table-4.11), we find that the mean floor area is 2444 square feet, and that the distribution is not normal (Table-4.12). The Shapiro-wilk test below confirms the non-normality (p-value < 0.05). However, post-regression diagnostics will reveal that this departure from normality does not affect the linear relationship between floor area and the dependent variable. Furthermore, Table 4.13 shows that the best transformation for normalising the variable would involve taking the logarithm. However, we did not undertake this transformation for the variable (See Section 4.1.3 for an explanation).

Table 4.11 - Floor Area

Percentiles		**Smallest**		
1%	752	637		
5%	890	752		
10%	1040	790	**Obs**	131
25%	1718	820	**Sum of Wgt.**	131
50%	2361		**Mean**	2440.099
Largest			**Std. Dev.**	1112.058
75%	2834	5610		
90%	3710	5744	**Variance**	1236672
95%	5170	5976	**Skewness**	1.074718
99%	5976	5980	**Kurtosis**	4.618415

Table 4.12 - Test for Normality - Floor Area

Variable	Obs	W	V	z	Prob>z
floorarea	131	0.92002	8.291	4.761	0.00000

Table 4.13 - Ladder-Test - Floor Area			
Transformation	formula	chi2(2)	P(chi2)
cubic	floora~a^3	.	0
square	floora~a^2	58.56	0
identity	floora~a	21.43	0
square root	sqrt(floora~a)	3.71	0.156
log	log(floora~a)	3.5	0.173
1/(square root)	1/sqrt(floora~a)	16.93	0
inverse	1/floora~a	33.18	0
1/square	1/(floora~a^2)	64.22	0
1/cubic	1/(floora~a^3)	.	0

Certification

For our study, the most important variable that is being tested is the 'certification' label. Those properties in our sample which are non-certified are given the value of '0'. As we can see in Table-4.14 below, about 70 percent of the properties in our sample do not have any green certification. Therefore, for every 'green' property there are approximately 3 non-green properties in the sample. In total, there are 36 green (LEED) properties in our sample. Furthermore, the LEED for homes rating system certifies homes according to four categories. A home is either certified (1), or receives one of three higher levels of certification comprising silver (2), gold (3), and platinum (4). In our sample, the vast majority of the certified buildings (72%) have received higher levels of certification.

Table 4.14 - Certification

CERT	Freq.	Percent	Cum.
0	95	72.52	72.52
1	5	3.82	76.34
2	5	3.82	80.15
3	12	9.16	89.31
4	14	10.69	100.00
Total	131	100.00	

Bedrooms

As can be seen below, a majority of the properties are moderately sized, and thus have 3-4 bedrooms.

Table 4.15 - Bedrooms

Bed	Freq.	Percent	Cum.
1	1	0.76	0.76
2	23	17.56	18.32
3	37	28.24	46.56
4	50	38.17	84.73
5	12	9.16	93.89
6	6	4.58	98.47
7	2	1.53	100.00
Total	**131**	**100.00**	

Bathrooms

As can be seen below, a majority of the properties are moderately sized, and thus have 3-4 bathrooms.

Table 4.16 - Bathrooms

Bath	Freq.	Percent	Cum.
1	12	9.16	9.16
2	23	17.56	26.72
3	38	29.01	55.73
4	31	23.66	79.39
5	15	11.45	90.84
6	5	3.82	94.66
7	5	3.82	98.47
8	2	1.53	100.00
Total	**131**	**100.00**	

Basement

Lastly, almost a third of the properties analysed in our sample contain a finished basement.

Table 4.17 - Basement

Basement	Freq.	Percent	Cum.
0	88	67.18	67.18
1	43	32.82	100.00
Total	131	100.00	

4.1.2 - Model Specification: Residential

So a large number of continuous and categorical variables have been presented for incorporation into the regression model. However, not all of them deserve entry into our model. There are a series of pre-regression standard tests and procedures we can follow to justify the variables which will eventually be included. They are described below:

a) Pearson correlations and Chi-square tests

It is crucial to test the correlations between the variables to ensure that strong linear relationships don't exist between our explanatory variables. Such relationships would make it difficult for the model to evaluate the *independent* effect of the explanatory variables upon market-value assessments of homes. In our list of variables, we have both continuous and categorical variables. To measure the linear relationships between continuous variables, the Pearson correlation technique is utilised (De Veaux et al., 2012). This is especially pertinent in our case as the OLS technique we are using is a linear regression method, and so there should not be linear relationships between the explanatory variables. In this case, a correlation of 1 is an indication of perfect linearity (or linear dependence) (De Veaux et al., 2012). For the categorical variables chi-square tests are performed.

Pearson correlation results - Residential

The continuous variables at our disposal are age, floor area, bedrooms, bathrooms, log-evaluation. Running a Pearson correlation command for these variables against each other in STATA yields the following relationships:

We can see (Table-4.18) that all the correlations are significant at the 5% level. From a regression perspective there are a couple of relationships that is of concern to us. Generally, a correlation of greater than 0.50 is considered a strong effect (Acock, 2012). In this case, there is a strong positive linear correlation between the number of bedrooms and the floor area (0.7). There is an even stronger positive correlation between the number of bathrooms and the floor area (0.8). Lastly, there is a strong positive correlation between the number of bedrooms and bathrooms (0.7). Given that these variables are potential explanatory variables in our model it would be unwise to leave them in. Hence, the number of bedrooms and bathrooms should be removed from our model. Given the fact that the two variables are correlated with each other, we

included floor area in the modelling exercise (since it has the strongest correlation vis-a-vis evaluation-adjusted).

Furthermore, the correlations between the log-evaluation variable and the explanatory variables are positive, significant at the five percent level, and so make for good potential explanatory variables in our model.

Table 4.18 - Pearson-Correlations - Residential Model

	Age	Floor Area	Bed	Bath	Evaluation
Age	1.0000				
Floor area	-0.3978* (0.0000)	1.0000			
Bedroom	-0.3392* (0.0001)	0.7110* (0.0000)	1.0000		
Bath	-0.4743* (0.0000)	0.8037* (0.0000)	0.6971* (0.0000)	1.0000	
Log-evaluation	-0.3136* (0.0003)	0.8163* (0.0000)	0.5884* (0.0000)	0.8398* (0.0000)	1.0000

Chi-Square Tests (Residential)

The list of potential categorical variables available for our model are; city-type, area-type, property-type, certification, shopping, food, and basement. For the sake of simplicity, only those variables which are potentially related have been modeled by this method. The results of those chi-square tests are presented in the table below:

With the exception of the last relationship, none of the relationships outlined below (Table-4.19) are significant at the chosen 5% level, since the chi-square statistics for all these relationships are too low given the degrees of freedom for each relationship. However, the third relationship between basement and property type do come close. There is a statistically significant relationship between the residential-city dummy variable and the property-type variable (perhaps due to the fact that all the suburban properties are single-detached homes). It would be prudent to think about dropping one of these variables. However, leaving these variables in the model did not create issues with multi-collinearity (see multi-collinearity test, post-regression for confirmation). Therefore, we continued to use them in the model.

Table 4.19 - Chi-Square Tests - Categorical Variable - Residential				
Relationship	Chi-Square	Probability	Degrees of Freedom	Significant at 5%?
Certification and Property type	2.08	0.98	8	No
Certification and Residential-city	5.07	0.280	4	No
Basement and Property Type	4.63	0.099	2	No
Residential-city and Property Type	18.18	0.000	2	Yes

To conclude, we have decided to proceed with all the variables discussed in the descriptive statistics section with the exception of the number of bedrooms and bathrooms variables. We are now, therefore, ready to proceed with model specification. Given that we are attempting to fit a linear multi-variable regression model, perhaps the most crucial test we must perform before fitting the model equation is to discern whether there are underlying linear relationships between our dependent (log-transformation of evaluation) and explanatory variables.

Model Specification: Test for Linearity

One of the elementary ways that the question of 'linearity' can be evaluated (ex-ante) is to plot a 'scatter-gram' of the dependent variable, in our case log-evaluation, versus each of the explanatory variables. The basic task is to assess whether a liner relationship can be discerned. Therefore, if there are "bends", the scatter-gram "fans" out, or other non-linear patterns can be detected, then remedial measures may need to be taken (De Veaux et al., 2012). A more formal linearity test is possible and will be done post-regression. Table-4.19 and Figures 4.3-4.10 below summarises the results of these scatter-grams produced by STATA. We can see that the plots reveal that almost all of our potential explanatory variables have a linear relationship with our explanatory variable, the log-evaluation (Table-4.19).

Table 4.19 - Linearity Tests	
Log-Evaluation Versus	**Result**
City type	Moderately Linear
Residential-city	Linear
Age	Moderately Linear
Property type	Linear
Floor area	Linear
Basement	Linear
Certification	Non-Linear

When we examine the graphs below we have one problematic relationship, that between log-evaluation and the stratified certification variable (broken into different levels). The graph (Fig-4.3) clearly indicates a curvature in the relationship (a sign of non-linearity between these variables). Therefore, our best option is to model certification in its 'binary' form, whereby '1' indicates that the home is certified and '0' indicates otherwise. We can also see from the other graphs that the relationships are fine for a linear fit.

Figure 4.3 Linearity Plot - Certification

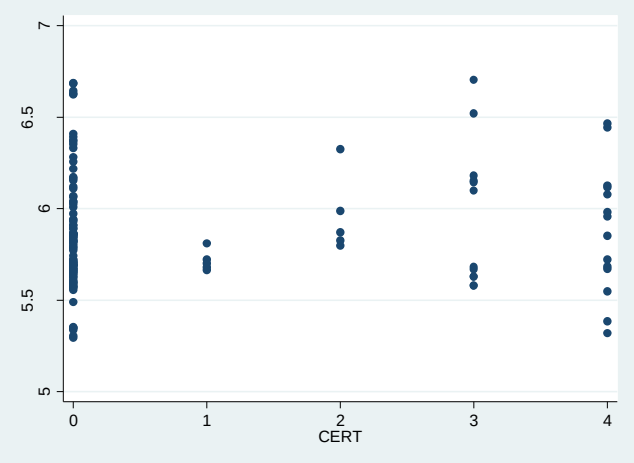


Figure 4.4 Linearity Plot - CERT

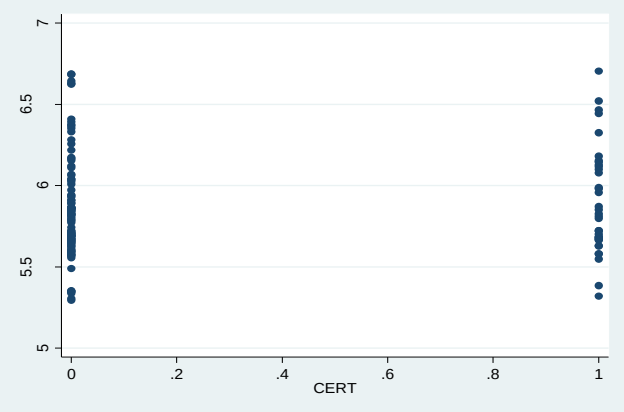


Figure 4.4 Linearity Plot - Residential

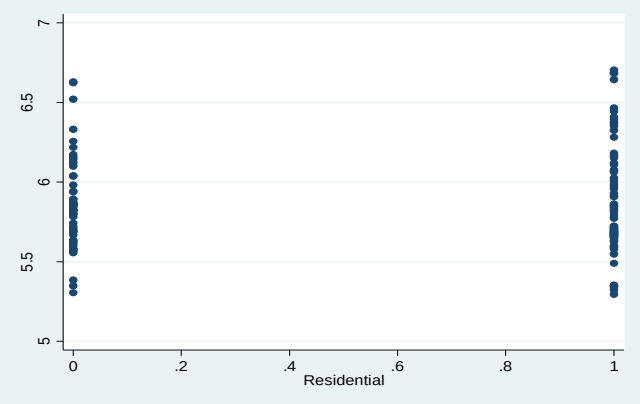


Figure 4.6 - Linearity Plot - Age

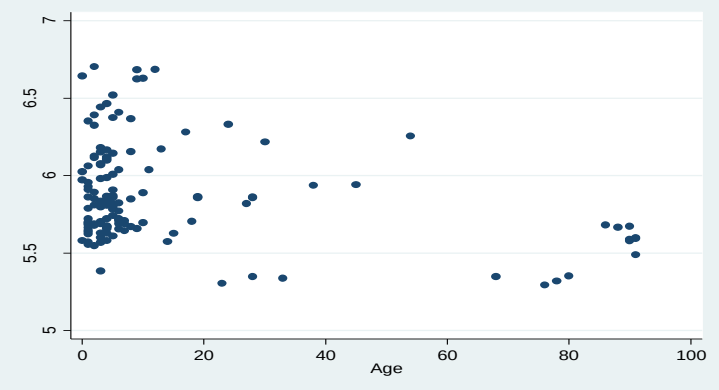


Figure 4.7 Linearity Plot - Property-Type

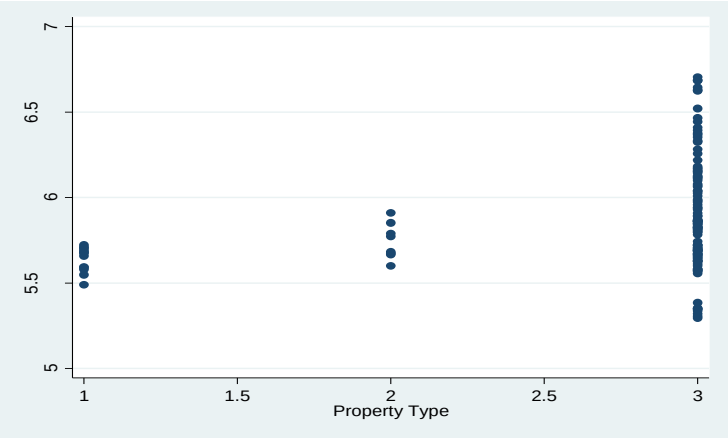


Figure 4.8 Linearity Plot - Floor Area

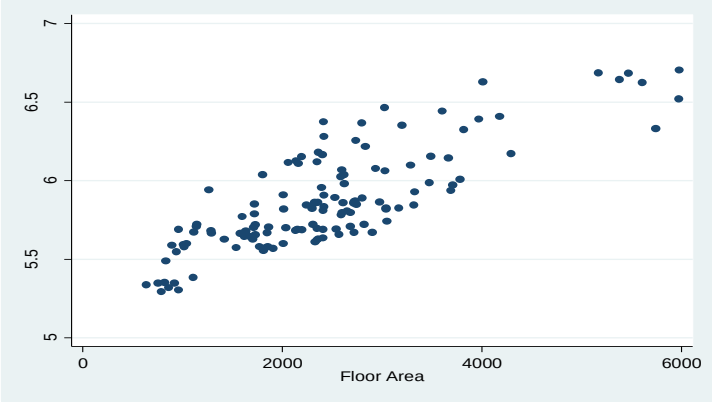


Figure 4.9 Linearity Plot - Basement

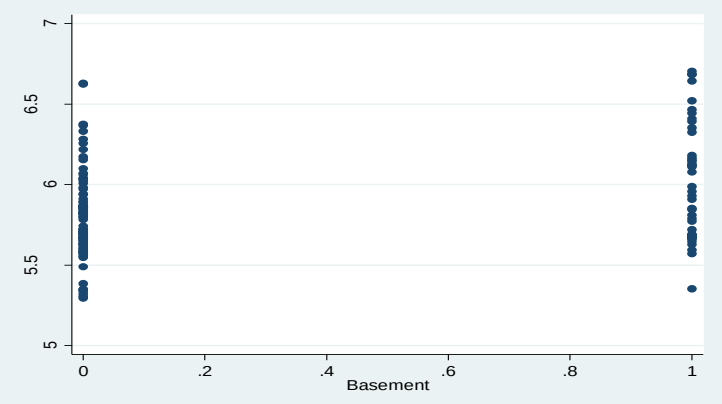
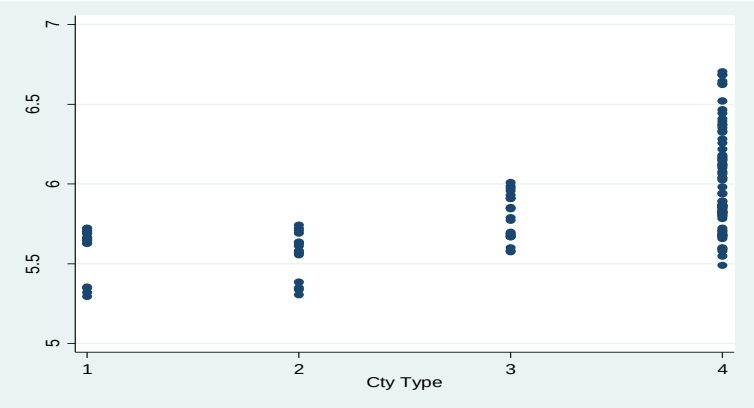


Figure 4.10 - Linearity Plot - City-Type



4.1.3- Residential Hedonic Model Results

As mentioned in the earlier methodology chapter, hedonic theory argues that the value (price) of a good (in this case, property) is related to the features and amenities connected with that property. Hence, the price of homes is dependent upon its main features. Using publicly available information, we have gathered data on the home amenities listed below:

- City type
- Area type
- Age
- Property type
- Floor area
- Certification
- Basement (yes/no)
- Bedrooms
- Bathrooms

The residential exercise will model the logarithm of evaluation to the city type variable broken into its constituent levels, the property type variable broken into its three levels, the certification variable broken into its constituent parts, two binary variable indicating the presence of a finished basement and the residential-city variable, with the floor area and age being the only continuous variables. The simple linear regression shown by the equation below was run on STATA Version 13:

Log-evaluation = β1 + β2 City-type + β3 Age + β4 Property-type + β5 Floor area + β6 Certification + β7 Basement + β8 Residential-city + μ

As we can see below (Table-4.20), the co-efficients are mostly of the expected sign (with the exception of the certfication variable- since the expectation was of a green premium) and statistically significant. The certification variable is negative, but is not significant. Therefore, we cannot conclude that there is a relationship between certification and market-value. Our overall explanatory model is sound as the F-value is 139.80, so we can reject the notion that this model is no better than comparing the means of the valuations of non-certified properties and certified properties (DeVeaux et al, 2012). Indeed, 85% of the variation in the dependent variable can be explained by our model, which is higher than most hedonic studies (see Literature-Review).

Table 4.20- Regression Results - Residential Model 1

Linear Regression					Observations	131
					F (10,120)	139.80
					Prob > F	0.0000
					R-Square	0.8494
					Root MSE	.12802
	Robust					
logevaluation	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
_Ictytype_2	0.038993	0.039006	1	0.319	-0.0382352	0.116222
_Ictytype_3	0.067434	0.037161	1.81	0.072	-0.0061414	0.141009
_Ictytype_4	0.320276	0.043157	7.42	0	0.2348269	0.405724
age	-0.00133	0.000506	-2.62	0.01	-0.0023282	-0.00032
_Ipropertyt_2	0.16266	0.052599	3.09	0.002	0.0585164	0.266803
_Ipropertyt_3	0.170698	0.051005	3.35	0.001	0.0697119	0.271684
floorarea	0.000167	1.41E-05	11.87	0	0.0001392	0.000195
certification	-0.02487	0.021405	-1.16	0.248	-0.0672465	0.017514
basement	0.094659	0.026348	3.59	0	0.0424909	0.146826
residential	0.119207	0.038031	3.13	0.002	0.0439072	0.194506
_cons	5.028626	0.068618	73.28	0	4.892768	5.164484

Residential Model - Regression Diagnostics

a- Errors are normally distributed?

Our distribution of errors for this model 'mirrors' normality but does not achieve it (Fig-4.11). Indeed, the normal probability (Fig-4.12) and the quintile probability plots (Fig-4.13) below reinforce this point as well. The problem seems to be in the tail ends, particularly at the higher end where we have some outlier values.

Figure 4.11 Histogram of Residuals - Residential Model 1

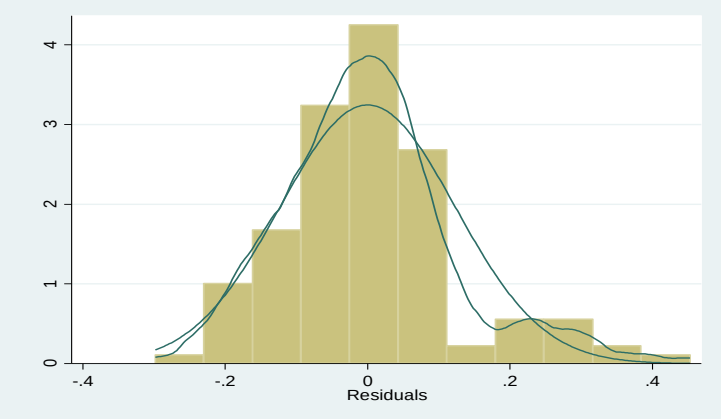


Figure 4.12 Normal Probability Plot - Residential Model 1

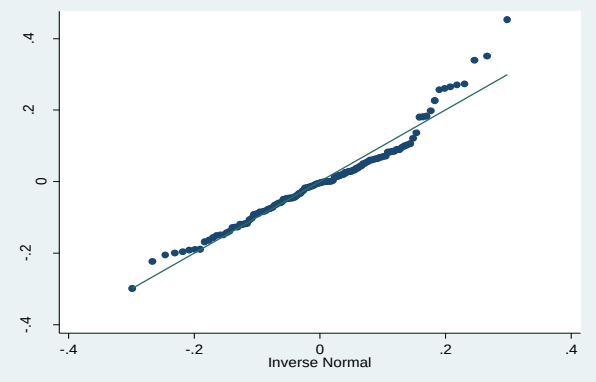
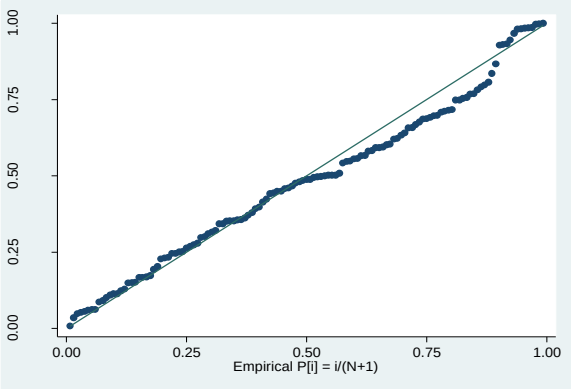


Figure 4.13 Quintile Probability Plot - Residential Model 1



The formal test to measure the normality of the residuals is the Shapiro-Wilk test (Table-4.21). This reinforces the need to correct again our residual non-normality issue. The p-value of 0.00049 is much less than the chosen alpha of 0.05 (5% of significance), hence we reject the notion that the distribution is normal.

Table 4.21 - Test for Error Normality

Variable	Obs	W	V	z	Prob>z
e	131	0.95826	4.326	3.297	0.00049

One of the underlying causes for why the residuals are not normally distributed could be the presence of outliers. These are observations that are so far removed from the mean that they cause the residuals to be abnormal, and they can even affect the overall model significance as they can tilt the co-efficient estimates away from the 'true' conditional mean (De Veaux et al, 2012). The STATA programme can help detect outliers through a listing of the residuals. We know that the problem with residual normality lies at the ends of the distribution (Fig. 4.12). As such, six observations from the model were removed by turn[29] (at the higher end) until the residuals reached an acceptable level of normality[30]. These observations are:

[29] Outliers were identified at the higher end by listing the residuals in ascending order, facilitating the detection of residuals whose values were exceptionally high in comparison to the other residuals in that numerical bracket.
[30] See Annex.1 for description of the outliers.

Table 4.22 Outliers - Residential Model		
Log-evaluation	Log-evaluation (predicted-values)	Residuals (e)
6.62857	6.175853	0.4527146
6.25585	5.904906	0.350947
6.37391	6.035321	0.3385917
6.36833	6.095471	0.2728588
5.94131	5.670846	0.2704639
6.21747	5.953101	0.2643656

Removing outliers can help raise the explanatory power of a model. Indeed, this is the case with our model as well. Once we ran the regression again without the outliers above we achieve the results outlined below (Table-4.23)**.** We can see the overall explanatory power of the model (the F-stat), increased from 140 to 159 as compared to the previous model. Furthermore, the variation of log-evaluation explained by the model increased from 85% to 90%. In terms of the statistical significance of the variables and their direction, there was no change (including the certification variable) from the first linear model. The certification binary variable exerts a 1% downward pull on market-value (when compared to non-certified homes), but this effect is not statistically significant. And so our overall conclusion remains the same[31].

[31] NOTE: Our original sample contained only 36 certified properties out of a total sample of 131 properties. Given this small proportion, there is a risk that there would be relatively few certified properties with higher valuations, and so regression results would be biased against the finding of any possible green premium. As such, in Annex 5, we present results of a model where the 'third' comparable for each subject property was removed. In this sample, there were 35 subject properties (1 outlier removed) and 66 comparable properties. However, as can be seen, the certification variable was not significant, and so our conclusion remains the same.

Table 4.23 Regression Results - Residential Model 2						
					Observations	125
					F (10,114)	158.76
					Prob > F	0.0000
					R-square	0.8967
					Root MSE	.10275
	Robust					
logevaluation	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
_Ictytype_2	0.038906	0.034787	1.12	0.266	-0.030006	0.1078186
_Ictytype_3	0.046088	0.035403	1.3	0.196	-0.024045	0.1162216
_Ictytype_4	0.277247	0.038653	7.17	0	0.2006758	0.3538176
age	-0.00175	0.000389	-4.5	0	-0.0025223	-0.0009795
_Ipropertyt_2	0.146954	0.048185	3.05	0.003	0.0514994	0.2424081
_Ipropertyt_3	0.117583	0.047682	2.47	0.015	0.0231256	0.2120408
floorarea	0.000169	1.27E-05	13.33	0	0.0001443	0.0001946
certification	-0.01081	0.020453	-0.53	0.598	-0.0513239	0.0297101
basement	0.115656	0.024267	4.77	0	0.0675834	0.1637282
residential	0.119414	0.031504	3.79	0	0.0570059	0.1818227
_cons	5.075452	0.064587	78.58	0	4.947507	5.203398

When we test again the normality of the residuals (Table-4.24), as expected, the residuals of the last regression modelling exercise are normally distributed, as indicated by the table below (p-value of 0.12 is higher than the chosen alpha of 0.05).

Table 4.24 - Test for Error Normality

Variable	Obs	W	V	z	Prob>z
e	125	0.98314	1.679	1.164	0.12218

b- Post-regression test for linearity

Using graphical analysis, we concluded that our underlying relationships were linear and so we proceeded with a linear multi-variate model. As a precaution, we can also perform a post-regression model check to reconfirm our earlier conclusion. The STATA software allows us to check for linearity post-regression using the 'acprplot' function. This command produces an augmented (component) partial residual plot using the post-regression errors which graphically

shows deviations from linearity (the linear regression line) and the severity of the deviance (STATA, 2014). When we plotted these graphs for age and floor area, we are able to see that there are no major deviations from linearity (Fig-4.14 & Fig-4.15).

Figure 4.14 Post regression test for normality - Age

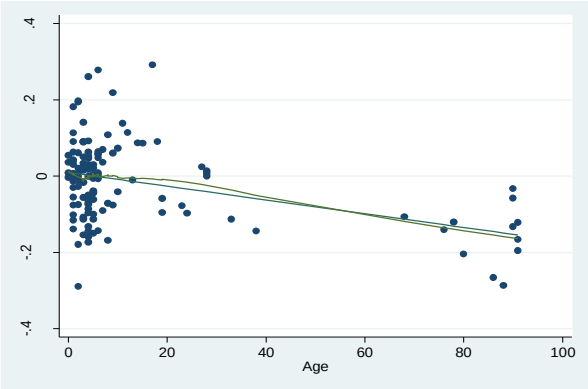
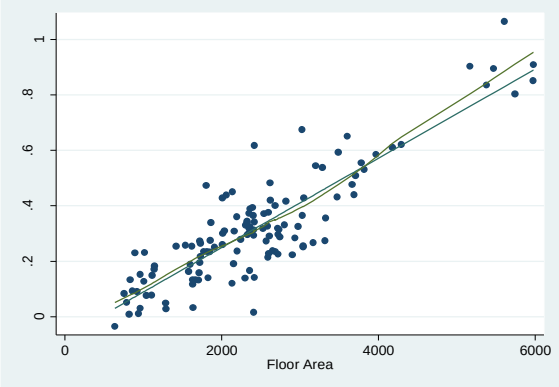


Figure 4.15 Post-regression test for linearity- Floor Area



c- Homo-skedasticity and Auto-Correlation Test

In order to check homo-skedasticity and auto-correlation we once again plot the residuals versus the predicted values of log-evaluation (as predicted by the model). Again, while we do not have equal variance (of no concern due to the use of 'robust regression'; hetero-skedasticity test does not apply), there are no bends and patterns in the plot that would give rise to concerns over auto-correlation (Fig-4.16). The second set of graphs plots the residuals versus potentially problematic explanatory variables like age and floor area (Fig-4.17, 4.18). In these cases, no discernible and worrying patterns and bends can be seen (a sign that the errors are correlated), hence, auto-correlation does not seem to be a problem.

Figure 4.16 Residual versus Fitted-Values

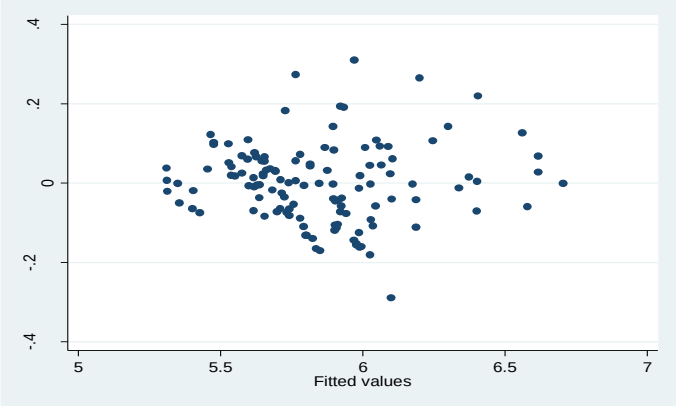


Figure 4.17 Residual versus Age

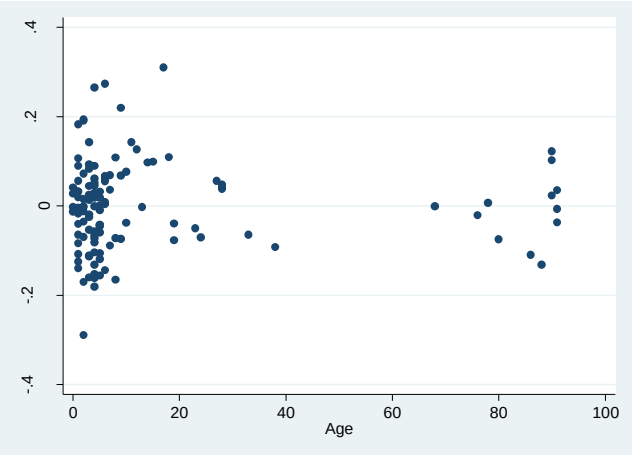
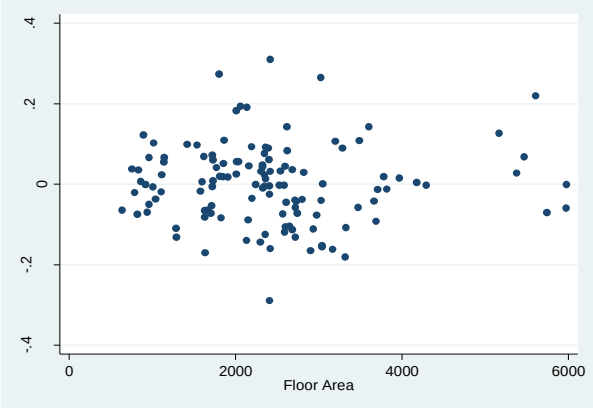


Figure 4.18 Residual versus Floor Area



d- Multi-collinearity Test

Lastly, we must check for multi-collinearity (Table-4.6), in which case some of the variables would need to be combined or removed from the model. There is no multi-collinearity present in our model that requires remedial measures (since the variance inflation factor (VIF) is under 10 for all the variables) (STATA, 2014).

Table 4.6 Test for Multi-Collinearity

Variable	VIF	1/VIF
_Ictytype_4	3.79	0.263527
_Iproperty~3	2.91	0.343382
_Ictytype_3	2.52	0.397576
_Ictytype_2	2.46	0.406392
residential	2.01	0.498273
floorarea	1.92	0.519519
_Iproperty~2	1.87	0.535987
basement	1.53	0.652963
age	1.53	0.655286
certificat~n	1.14	0.875717
Mean VIF	2.17	

Note: Our analysis showed that the best option for normalising age and floor area was to take the square-root of age and the logarithm of floor area. Given that the log-linear model was the simplest to interpret and post-regression tests did not present any issues with linearity, we decided to not transform those variables. However, in the Annexes 3 & 4, we present two analyses where the dependent variable is first the logarithm of evaluation-adjusted and secondly, the inverse square-root of evaluation-adjusted. In both models age and floor area are transformed. One can see that our results do not change with respect to our main question, and all assumptions for OLS analysis are met.

4.2- Hedonic Model: Commercial

4.2.1- Descriptive Statistics: Commercial

Evaluation-Adjusted

As in the case of the residential model, the valuations of the commercial properties also had to be adjusted to a specific point in time. A summary of this variable is provided below. The adjusted-average valuation is $77.2 million dollars. The property in the 1-percentile has a value of $2.7 million, and the one in the 99-th percentile is valued at $781 million. The variable is not normally distributed, shown by the Shapiro-Wilk test for normality (p-value < 0.05) (Table-4.27).

Table 4.26 - Evaluation-Adjusted

Percentiles		Smallest		
1%	2779000	2307000		
5%	8417000	2779000		
10%	1.10e+07	3266560	**Obs**	192
25%	2.27e+07	3875300	**Sum of Wgt.**	192
50%	5.28e+07		**Mean**	7.72e+07
		Largest	**Std. Dev.**	1.03e+08
75%	9.44e+07	2.96e+08		
90%	1.62e+08	3.80e+08	**Variance**	1.07e+16
95%	2.10e+08	7.81e+08	**Skewness**	5.198199
99%	7.81e+08	9.55e+08	**Kurtosis**	39.54197

Figure 4.19 - Histogram - Evaluation Adjusted

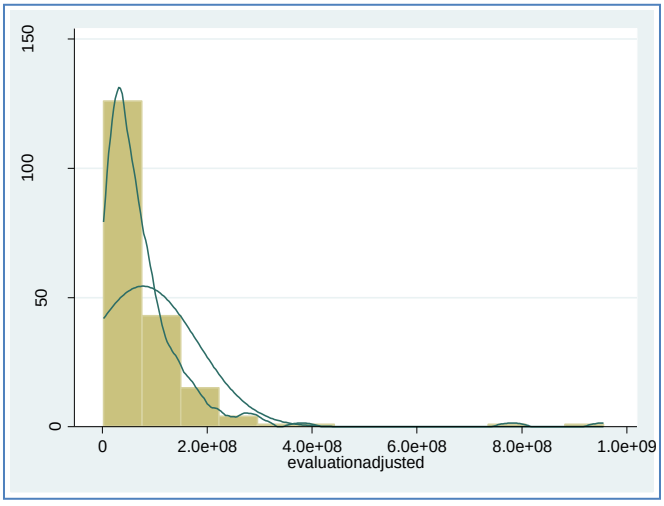


Table 4.27 Test for Normality - Evaluation-Adjusted

Variable	Obs	W	V	z	Prob>z
evaluation~d	192	0.55115	64.626	9.572	0.00000

We can use the 'ladder' test to assess how we can bring about a more 'normal' transformation for this variable (Table-4.29). The results are illustrated below:

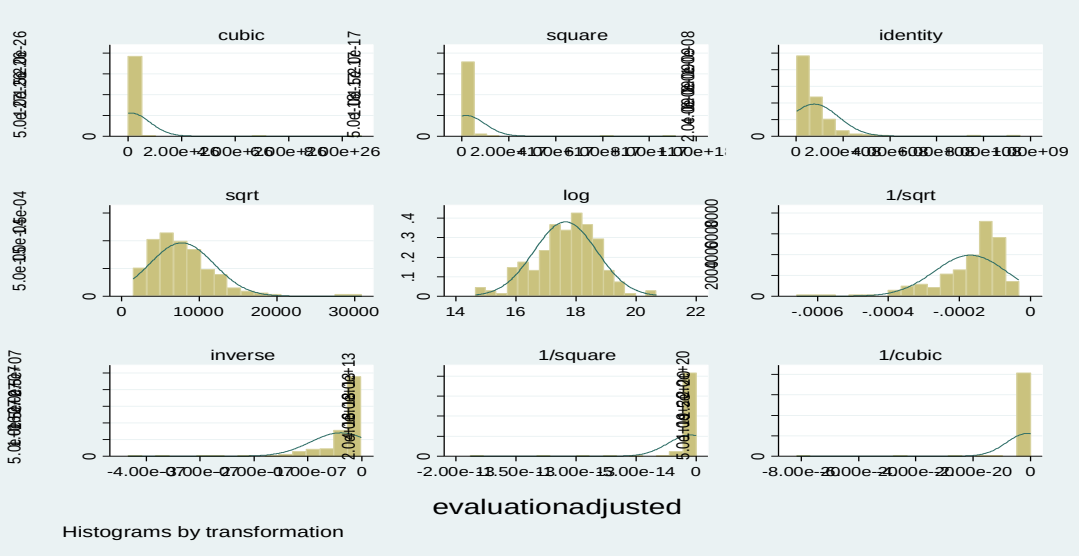
Clearly, we can see that log transformations provide the best potential (lowest value of chi-2 statistic) for normalising our dependent variable. Indeed, when we perform the Shapiro-Wilk test for normality, the results are positive as the p-value (0.17) is much higher than the 5% (or alpha = 0.05) level of significance. Therefore, the normality of the dependent variable is an assumption we are able to meet comfortably in this model, and the dependent variable is the logarithmic transformation of the adjusted market-value assessment (log-evaluation).

Table 4.28 - Test for Normality - Log-Evaluation

Variable	Obs W	V	z	Prob>z
logevaluat~n	192 0.98957	1.501	0.933	0.17542

Table 4.29 - Ladder Test - Commercial Model			
Transformation	formula	chi2(2)	P(chi2)
cubic	evalua~d^3	.	0
square	evalua~d^2	.	0
identity	evalua~d	.	0
square root	sqrt(evalua~d)	67.93	0
log	log(evalua~d)	2.63	0.268
1/(square root)	1/sqrt(evalua~d)	65.19	0
inverse	1/evalua~d	.	0
1/square	1/(evalua~d^2)	.	0
1/cubic	1/(evalua~d^3)	.	0

Figure 4.20 - Ladder Test Histograms - Evaluation-Adjusted



Property Class

As is the case with residential properties, commercial properties are also classified into different types or 'classes'. The property class-type as a variable has been used in at least three hedonic studies by Dermisi (2009), Eichholtz (2010), and Fuerst and Mcallister (2011). For the purposes of this research paper, three different classes of properties were examined, they are A, B, and C. Properties classed G were taken out of the equation as they are government assets and are perhaps not exposed to the same market forces as other classes of properties. One can think of buildings in the A category as exemplifying a higher quality of building (typically greater floor space and with more amenities), with the B and C categories progressively lower. While there is a risk that this variable captures information that are already incorporate in other variables, we will include it for now (and perform chi-square tests later to check for issues inclusion may potentially cause).

In the model, properties classed as C were given a code of '0', those that are B were given the code of '1' and so the A's were given the code '2'. As we can see from Table-4.30 below, the majority of the office buildings in the sample come from the B class, and only 10% come from the C class of buildings.

Table 4.30 - Property-Class

Class	Freq.	Percent	Cum.
0	20	10.42	10.42
1	101	52.60	63.02
2	71	36.98	100.00
Total	192	100.00	

Floors

The number of floors is also a relevant variable to include as they perhaps entail a certain level of prestige and office space availability. As can be seen from Table-4.31 below, the average number of floors for the buildings is about 14. The buildings go from being simple 1-story office spaces to large skyscrapers over 40 stories tall. The Shapiro-Wilk test also confirms non-normality (p-value < 0.05) (Table-4.32).

Table 4.31 - Number of Floors

Percentiles		Smallest		
1%	1	1		
5%	3	1		
10%	4	2	**Obs**	192
25%	7	2	**Sum of Wgt.**	192
50%	14		**Mean**	14.15625
		Largest	**Std. Dev.**	8.274515
75%	20	33		
90%	25	34	**Variance**	68.4676
95%	30	34	**Skewness**	.4775045
99%	34	40	**Kurtosis**	2.625968

Table 4.32 - Test for Normality- Floors

Variable Obs	W	V	z	Prob>z	
floors	192	0.96479	5.069	3.727	0.00010

Typical Floor

The typical floor size could be an important variable affecting the market-value since prospective clients may have a preference with respect to how big the average floor is, the convenience and comforts that this entails in terms of noise, mobility, space, etc. This is not a variable which has

been used before as far as we have investigated, but we can at least consider its merits given that this type of information is available for us and is widely reported by real-estate management companies. The mean typical floor area in the sample is just over 17,000 square feet. The Shapiro-Wilk test also confirms non-normality (p-value < 0.05) (Table-4.34).

Table 4.33 - Typical Floor

Percentiles		**Smallest**		
1%	5594	4610		
5%	7800	5594		
10%	8800	5916	**Obs**	192
25%	10750	6237	**Sum of Wgt.**	192
50%	13800		**Mean**	17015.14
Largest			**Std. Dev.**	11454.71
75%	19150	60000		
90%	30000	61847	**Variance**	1.31e+08
95%	38000	80000	**Skewness**	3.043006
99%	80000	85000	**Kurtosis**	15.03177

Table 4.34 - Test for Normality - Age

Variable	Obs	W	V	z	Prob>z
typical	192	0.69009	44.622	8.721	0.00000

Age

The age of any property (or asset) is an important variable to consider when one is studying valuation. Buildings, like all tangible assets, depreciate over time, and so age could be an important predictor of value. In our sample, there is a wide range of ages as there are buildings which are only 2-years old, included with those that are well over a century old. The average age of the buildings in our sample is just over forty years. The non-normality of the variable is also confirmed by the Shapiro-Wilk test as well (p-value < 0.05) (Table-4.36).

Table 4.35- Age

Percentiles		Smallest		
1%	4	2		
5%	9	4		
10%	20	5	**Obs**	192
25%	29.5	6	**Sum of Wgt.**	192
50%	34		**Mean**	40.01042
		Largest	**Std. Dev.**	22.93081
75%	46	112		
90%	77	113	**Variance**	525.8219
95%	94	123	**Skewness**	1.568508
99%	123	136	**Kurtosis**	6.042151

Table 4.36 - Test for Normality - Age

Variable	Obs	W	V	z	Prob>z
age	192	0.85308	21.153	7.007	0.00000

Floor area

In addition to the typical floor area, the total floor area is of crucial importance, clients want to know if there is overall sufficient space for their business needs. The average total floor space is over 214,000 square feet. On the smaller end, the 1-percentile group is at 17,517 square feet, while the largest buildings in the 99th percentile group are over 940,000 square feet. In terms of distribution, it is non-normal and is positively skewed. The Shapiro-Wilk test also confirms non-normality of the variable (p-value < 0.05) (Table-4.38).

Table 4.37 - Floor Area

Percentiles		Smallest		
1%	17517	17077		
5%	40000	17517		
10%	51652	22923	**Obs**	192
25%	93377	24026	**Sum of Wgt.**	192
50%	185823		**Mean**	214145.6
		Largest	**Std. Dev.**	163699.7
75%	269000	650448		
90%	417833	898700	**Variance**	2.68e+10
95%	523000	943630	**Skewness**	1.814443
99%	943630	968297	**Kurtosis**	7.719422

Table 4.38 - Test for Normality - Floor Area

Variable	Obs	W	V	z	Prob>z
floorarea	192	0.84894	21.750	7.071	0.00000

District

When it comes to value, not all geographical areas within a municipality entail the same level of convenience, visibility, networking opportunity, or neighborhood amenities. As such, for the purpose of our research, office districts were segmented and categorised according to whether the building was in the suburbs (0), downtown (1), or in the downtown core (2). The use of categorical variables to indicate 'geography' or proximity to the central business district has been used by Pivo and Fisher (2010), Dunse and Jones (1998), and Miller et al. (2008). As can be seen below (Table-4.39), the vast majority of the buildings are based in the downtown core, this group comprises 57% of the office buildings in the sample.

Table 4.39 - District

District	Freq.	Percent	Cum.
0	21	10.94	10.94
1	61	31.77	42.71
2	110	57.29	100.00
Total	192	100.00	

Shopping

Increasingly, buildings are incorporating various on-site features which include shopping facilities. It is a convenience that some value in that shopping can be done right after or during the workday. At the same time, it provides building management companies an added source of revenue thus maximising the economic potential of available floor space. However, in our sample only twenty percent of the buildings contain in-house shopping facilities (Table-4.40). This may be due to the fact that it requires a building of a certain size to have enough space and/or clientele to make this service available or viable financially. In our model, 'shopping' indicates the presence of a convenience store/market and/or more elaborate facilities.

Table 4.40 - Shopping

Shopping	Freq.	Percent	Cum.
0	153	79.69	79.69
1	39	20.31	100.00
Total	192	100.00	

Food

Similar to onsite shopping amenities, food courts and restaurants are potentially positive amenities as well as they enhance the convenience of building occupants. However, similar to shopping facilities, onsite food services are offered by only a quarter of the buildings in the sample (Table-4.41). This could be due to the handicap of having limited space and/or clientele in the building.

Table 4.41 - Food

Food	Freq.	Percent	Cum.
0	145	75.52	75.52
1	47	24.48	100.00
Total	192	100.00	

Fitness

The productivity of employees may be enhanced by providing space and facilities for recreational activities, such as fitness areas and gyms. In our sample, just over 13% of the commercial buildings provide this service to their clients (Table-4.42).

Table 4.42 - Fitness

Fitness	Freq.	Percent	Cum.
0	166	86.46	86.46
1	26	13.54	100.00
Total	192	100.00	

Certification

The BOMA best certification is divided into 4 levels (Levels 1, 2, 3, 4) with the number 4 being the most 'green' rating. Those in our sample of commercial properties with the rating '0' are properties which are not certified by BOMA or any other certification as of the market-valuation

period under study. Approximately 65% of the commercial properties in our sample are not certified. As we can see below, most of the certified properties have achieved a level 2 or 3 (Table-4.43).

Table 4.43 - Certification

	Freq.	Percent	Cum.
0	124	64.58	64.58
1	11	5.73	70.31
2	29	15.10	85.42
3	25	13.02	98.44
4	3	1.56	100.00
Total	192	100.00	

4.2.2- Model Specification: Commercial

Now that we have introduced all the variables which are available for the regression exercise, we must follow the same procedures as before to narrow down the set of variables we want to model. Therefore, as before, we tested Pearson correlations for the continuous variables, and chi-square tests for the categorical variables. This will be followed by tests for linearity and step-wise regression.

a) Pearson Correlations and Chi-Squared tests

There are four continuous variables in our sample, typical floor, the number of floors, age, and floor area. These four variables were correlated against each other and the dependent variable log-evaluation to assess the strength of their relationships, and their significance at the 5 percent level is described below in Table-4.44. The first relationship that is striking is the one between the floor area variable and the number of floors. This correlation is classified as strong because it's above 0.50 and is statistically significant at the 5% level. Given the strength of this linear correlation, it is best to leave the number of floors out of the model. Also, floor area has strong correlation vis-a-vis log-evaluation, and is the explanatory variable which appears most in the commercial hedonic studies reviewed (see Chapter.2), therefore, it is best to include it in the model.

We can also take note of the fact that there is a statistically significant moderate correlation between typical floor area and floor area. Therefore, we will also take typical floor out of the modelling exercise (typical floor area has a weak and statistically-insignificant correlation with the log-evaluation variable. Lastly, the dependent variable has a significant and strong relationship with the number of floors and floor area, while typical floor area and age seem to have weak relationships with the dependent variable log-evaluation.

Table 4.44- Pearson-Correlations - Continuous Variable - Commercial Model

	Typical floor	Floors	Age	Floor Area	Log-evaluation
Typical floor	1.0000				
Floors	-0.1888* (0.0087)	1.0000			
Age	-0.0763 (0.2932)	-0.0162 (0.8238)	1.0000		
Floor Area	0.3445* (0.0000)	0.6805* (0.0000)	0.0264 (0.7166)	1.0000	
Log-evaluation	0.1238 (0.0871)	0.7238* (0.0000)	-0.1123 (0.1209)	0.7160* (0.0000)	1.0000

Chi-Square Tests

The next step is to test the categorical variables for any underlying relationships amongst them. We have seven categorical variables available to us for use. They are certification (5 levels), class (3 levels), district (3 levels), shopping, food, fitness. The most relevant relationships are described below. There are three relationships which are of concern to us, the ones between office district and class, food facilities and class, and certification and class. These relationships are also significant at the 5% level (Table-4.45).

The obvious solution would be to take the common (class) variable out of the equation, thus, we will proceed without office class as a variable in our model.

Table 4.45 Chi-Square Tests - Categorical Variables- Commercial Models

Variables	Chi-Square	Degrees of Freedom	Probability	Significance 5%
District and Class	10.4505	4	0.033	Yes
Shopping and Class	2.9285	2	0.231	No
Food and Class	9.0542	2	0.011	Yes
Fitness and Class	2.1991	2	0.333	No
City and Certification	0.0380	1	0.845	No
Class and Certification	6.8699	2	0.032	Yes
District and Certification	0.0921	2	0.955	No

Model-Specification : Tests for Linearity

We have thus far, eliminated three variables from our list they are property class, typical floor area, and the number of floors. We are thus left so far with seven candidate explanatory variables.

An assumption a variable must meet in order to be included in the model, is that it must have a linear association with our dependent variable, log-evaluation. As a preliminary step we can look at the graphical association between our explanatory variables and log-evaluation. The key question is to evaluate whether a linear relationship can be discerned between the dependent and explanatory variables. Table-4.46 below summarises some of the results obtained from this exercise, and is followed by the graph matrix.

Table 4.46 Linearity Tests - Commercial

	Versus
Age	Moderately linear
Floor area	Curvature (non-linear)
District	Linear
Shopping	Linear
Food	Linear
Fitness	Linear
Certification	Moderately-Linear

Figure 4.21 Test for Linearity - Age

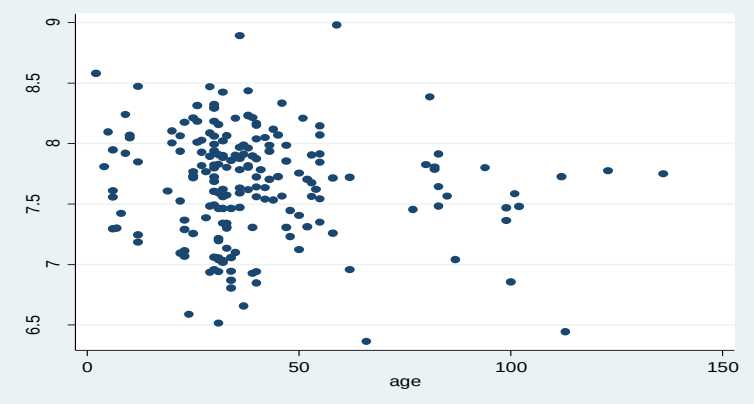


Figure 4.22 Test for Linearity - Floor Area

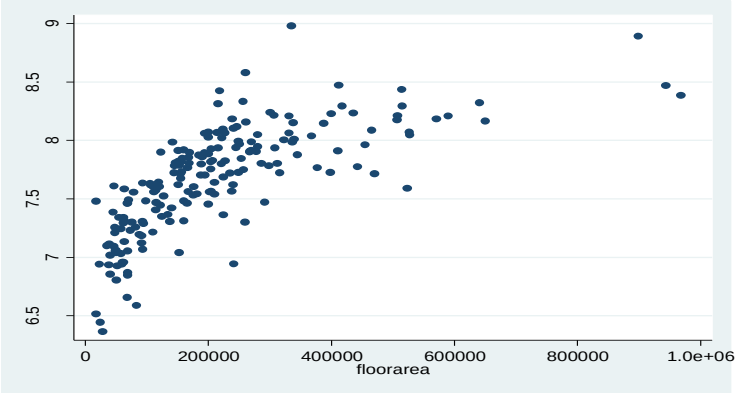


Figure 4.23 Test for Linearity - District

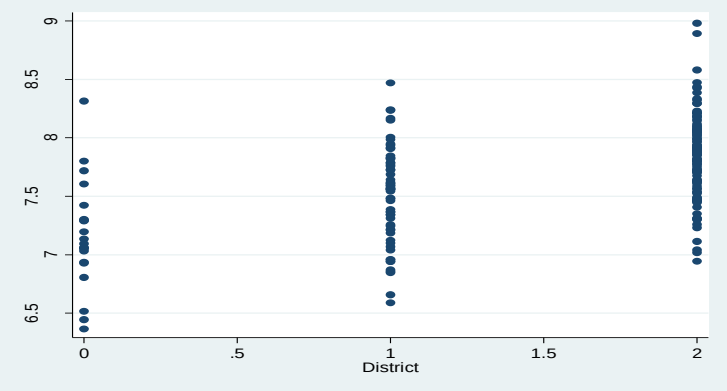


Figure 4.24 Test for Linearity - Shopping

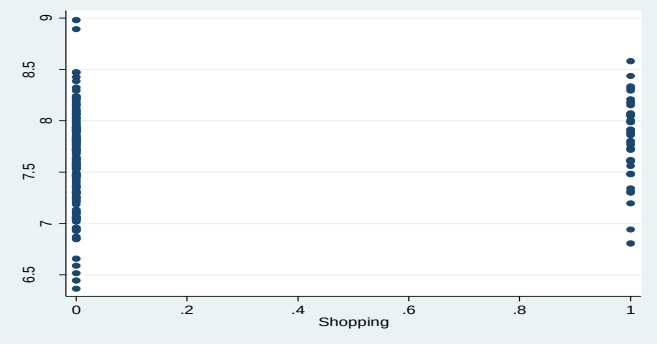


Figure 4.25 Test for Linearity - Food

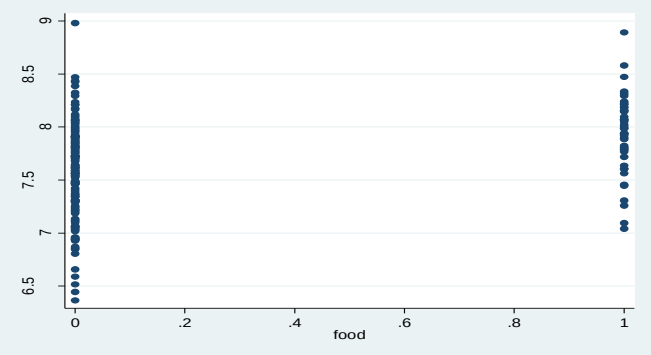


Figure 4.26 - Test for Linearity - Fitness

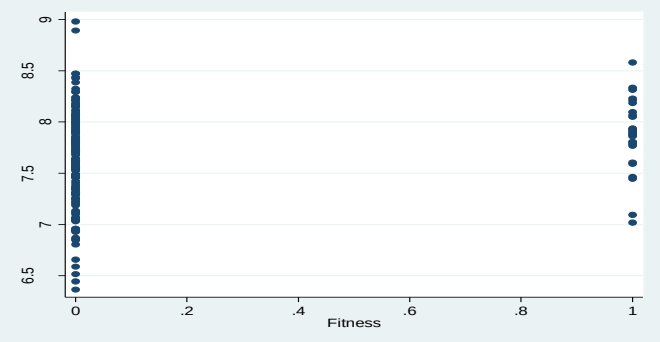
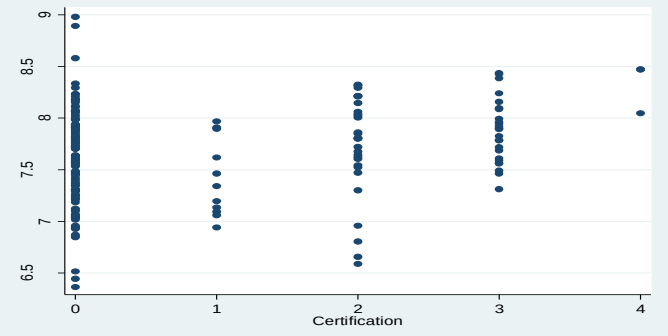


Figure 4.26 - Test for Linearity - Certification



Clearly, there is an issue with linearity given one non-linear relationship (with floor area) and one that is weakly linear (age). In the case of floor area, the scatter-gram shows a clear curvature in the relationship.

An underlying reason for why there could be a non-linearity issue is related to the fact that the variables are not normally distributed. Indeed, the Shapiro-Wilks test applied to both variables yielded a p-value of 0.0000 in both cases, obviously much lower than the 5% level of

significance. To correct for this, we can do ladder tests to see how the variables can be transformed, and see if that improves results. As we can see from Table-4.47 below, by taking the square-root of the age variable and the logarithm of floor area, we may be able to develop a more linear relationship vis-a-vis log-evaluation.

Table 4.47 - Ladder Test - Floor Area and Age - Commercial

Transformation	formula	chi2(2)	P(chi2)
cubic	floora~a^3	.	0
square	floora~a^2	.	0
identity	floora~a	62.1	0
square root	sqrt(floora~a)	12.61	0.002
log	**log(floora~a)**	**5.08**	**0.079**
1/(square root)	1/sqrt(floora~a)	45.77	0
inverse	1/floora~a	.	0
1/square	1/(floora~a^2)	.	0
1/cubic	1/(floora~a^3)	.	0
Transformation	formula	chi2(2)	P(chi2)
cubic	age^3	.	0
square	age^2	.	0
identity	age	49.37	0
square root	***sqrt(age)***	***11.51***	***0.003***
log	log(age)	38.94	0
1/(square root)	1/sqrt(age)	.	0
inverse	1/age	.	0
1/square	1/(age^2)	.	0
1/cubic	1/(age^3)	.	0

The two graphs below (Fig-4.28 and 4.29) illustrate that by undertaking these two transformations we can dramatically improve the linearity issue for the floor area variable and create a slight improvement for the age variable (the graphs slow relatively smooth linear relationships). Therefore, for fitting our model will use the log of floor area and the square-root of age. Also, post-linearity checks will confirm this.

Figure 4.28 Test for Linearity - Log Floor Area

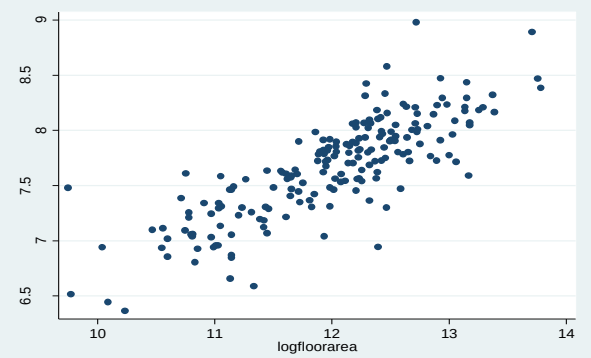
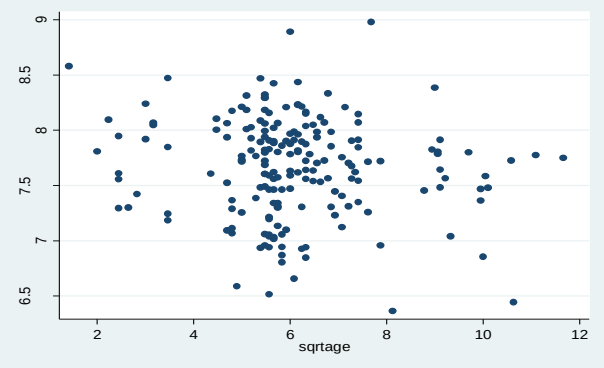


Figure 4.29 Test for Linearity - Square-root of Age



4.2.3- Commercial Hedonic Model Results

When one peruses the commercial hedonic literature, there are some features which stand out as being potentially strong contributors to value (see end of Chapter.2). Many of these same variables have also been utilised in our commercial hedonic model being tested in this paper. In our case, the potential variables include:

- Certification
- Property Class
- Floors
- Typical floor
- Age
- Floor area
- Office district

- Shopping (amenities onsite)
- Food (onsite)
- Fitness (onsite)

Now that we have finalised the variables in our model, we can proceed to run the linear regression equation described below:

Log-evaluation = β1 + β2 Certification + β3 Square-Root Age + β4 Log-Floor area + β5 District + β6 Shopping + β7 Fitness + μ

Most of the non-certification variables have the expected signs and are statistically significant (Table-4.48). Most of the certification variable levels are not significant (when compared with non-certified properties). However, certification Level 3 seems to add a statistically significant premium to a building of 9% on average when compared with non-BOMA BEST properties[32]. This is the only evidence of a green market-valuation premium that we have obtained throughout this exercise. However, given that it is a bit of an anomaly within this model (other certification levels are non-significant), we need to interpret this cautiously. Hence, one should again conclude that there is still no conclusive evidence (positive and statistically-significant regression co-efficients) that a green premium (in terms of market-valuation) exists in the commercial sector when we examine Canada's major metropolitan business centres.

[32] NOTE: The certification and district variables are composed of multiple levels. Hence, the co-efficient for each is an indication of the average effect (in percentage) of each 'level' of that variable on log-evaluation, as compared to a property which is not certified (or located in the suburbs).

Table 4.48 Regression Results - Commercial Model 1						
Linear	regression				Number of obs	192
					F(10, 181)	74.08
					Prob > F	0
					R-squared	0.7446
					Root MSE	0.23598
		Robust				
logevaluation	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
_Icertifica_1	0.030573	0.0439683	0.7	0.488	-0.0561831	0.11733
_Icertifica_2	-0.03563	0.0553802	-0.64	0.521	-0.1449005	0.073647
_Icertifica_3	0.099309	0.0443559	2.24	0.026	0.0117876	0.18683
_Icertifica_4	0.066675	0.1773598	0.38	0.707	-0.2832842	0.416633
sqrtage	-0.02756	0.0111188	-2.48	0.014	-0.0494982	-0.00562
logfloorarea	0.405649	0.0320569	12.65	0	0.3423959	0.468903
_Idistrict_1	0.120887	0.0599312	2.02	0.045	0.0026333	0.239141
_Idistrict_2	0.258038	0.0611659	4.22	0	0.1373479	0.378728
shopping	0.131183	0.0456127	2.88	0.005	0.0411821	0.221184
fitness	0.132441	0.0477002	2.78	0.006	0.0383208	0.226561
_cons	2.726792	0.332375	8.2	0	2.070964	3.38262

a - Are the residuals normally distributed?

Plotting the histogram of the residuals shows a mostly normal distribution but is skewed at the ends (Fig-4.30). The normal probability plot and the quintile-normal plot show similar patterns as before with slight extremity at the ends (Fig-4.31 & 4.32). The Shapiro-Wilk test yields the same result as we saw in the earlier residential model (Table-4.49), non-normality of the residuals (since the p-value of 0.00002 is less than the chosen significance level of 5%).

Figure 4.30 Error Normality - Commercial Model 1

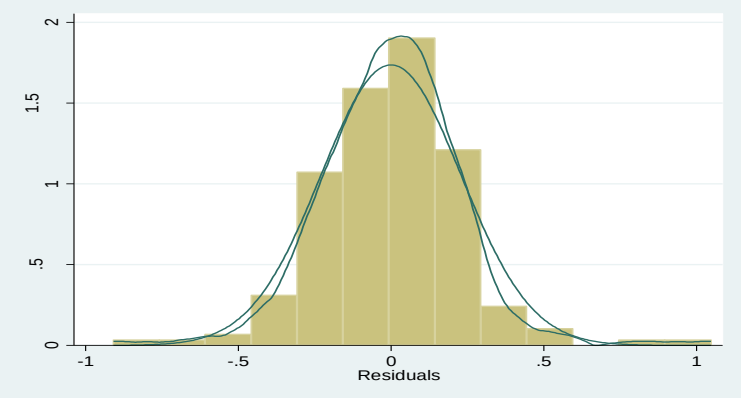


Figure 4.31 Normal Probability Plot - Commercial 1

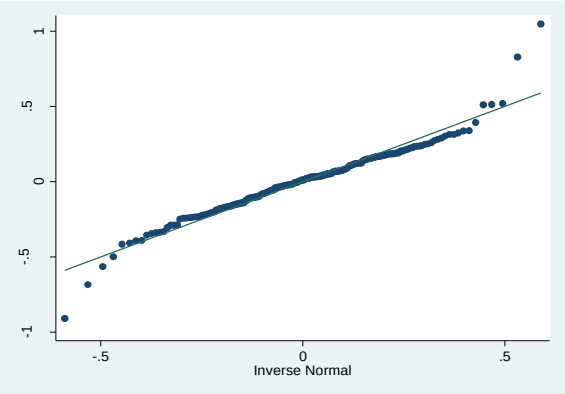


Figure 4.32 Quintile Probability Plot - Commercial 1

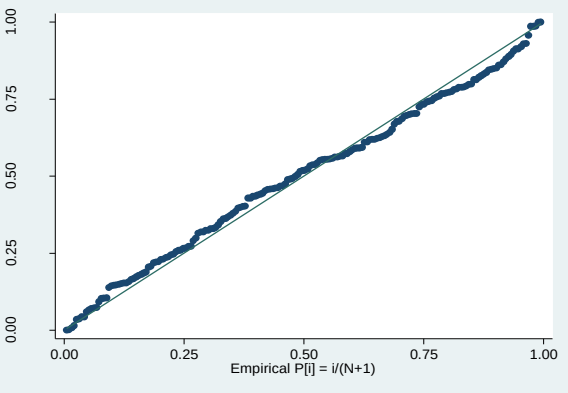


Table 4.49 - Test for Error Normality - Commercial

Variable	Obs	W	V	z	Prob>z
e	192	0.95748	6.122	4.160	0.00002

We can utilize the same procedure to correct for this issue as we did before, by removing the key outliers. When we repeated the steps taken before (listing the dependent variable, predicted values, and the errors), there were three observations which turned out to be problematic (the observations with the highest two errors, and the lowest (Table-4.50)[33].

[33] See Annex.1 for description.

Table 4.50 Outliers - Commercial Model		
Log-evaluation	Log-evaluation (predicted)	Error-value
6.9425	7.851931	-.9094347
7.48101	6.653778	.8272359
8.98019	7.933269	1.046917

When we eliminated these observations from our model, the p-value of the Shapiro-Wilk test rose significantly from 0.00002 to 0.27 (Table-4.51). Thus, we can be confident that the residuals are distributed normally, going by the 5% level of significance.

Table 4.51 - Test for Error Normality - Commercial

Table 4.10 Error Normality - Shapiro-Wilk					
Variable	Obs	W	V	z	Prob>z
e	189	0.99079	1.308	0.616	0.26898

We ran again our model with these observations removed. The results below show a strengthening of the overall explanatory power of the model as the F-stat rises from 74 to 91, and the variation of the dependent variable that is explained by our model also rises from 74.5% to 80%. In terms of the direction of causation of the co-efficients and their significance, there is no change from the previous model (Table-4.52)**.**

A further explanation is required with respect to the categorical variables which have been broken up into their individual level, that is, the certification and office district variables. In both cases, the base variable is the "lower" level. Therefore, in the case of the certification variable, the base-case is a non-certified office building, and for the office district variable it is a building situated in the suburbs. Therefore, our model points out that being situated in the core district adds a premium of 24% to market-value when compared to suburban office properties, and this effect is statistically significant. Likewise, in the case of certification, having a level-4 certification adds a premium of 3.3% to market-value in comparison to non-certified properties, but this effect is not statistically significant.

Table 4.52 Regression Results - Commercial Model 2						
Linear	regression				Number of obs	189
					F(10, 178)	91.33
					Prob > F	0
					R-squared	0.8021
					Root MSE	0.20329
		Robust				
logevaluation	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
_Icertifica_1	0.046351	0.0401	1.16	0.249	-0.0327807	0.125483
_Icertifica_2	-0.02762	0.05301	-0.52	0.603	-0.1322244	0.076994
_Icertifica_3	0.099283	0.043189	2.3	0.023	0.0140549	0.184512
_Icertifica_4	0.033192	0.169428	0.2	0.845	-0.3011541	0.367538
sqrtage	-0.03846	0.008871	-4.34	0	-0.0559625	-0.02095
logfloorarea	0.42403	0.02557	16.58	0	0.3735702	0.474489
_Idistrict_1	0.101016	0.05738	1.76	0.08	-0.0122168	0.21425
_Idistrict_2	0.24407	0.060068	4.06	0	0.1255325	0.362607
shopping	0.09966	0.036604	2.72	0.007	0.0274261	0.171894
fitness	0.132818	0.046641	2.85	0.005	0.0407785	0.224858
_cons	2.586124	0.273041	9.47	0	2.04731	3.124937

b- Homo-skedasticity and Auto-correlation

As we can see below (Fig-4.33), the plot of the residuals versus the fitted values gave us a similar pattern to what we saw earlier, no thickening, a confirmation of linearity. So while we did not achieve homo-skedasticity, given that the thickness of the residuals vary (we are using robust estimation, which does not assume it), it does not look like there is a problem with auto-correlation either, as there are no obvious patterns which can be detected from the partial plots. Also, fitting the residuals versus the log-floor area and square-root of age variables show no patterns either Figure-4.34, 4.35.

Figure 4.33 Residual versus Fitted Values - Commercial Model 2

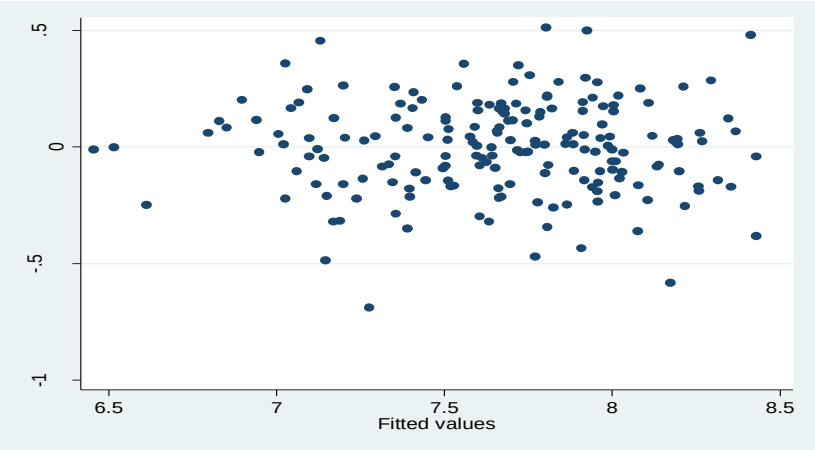


Figure 4.34 Plot of residual versus Log-Floor Area

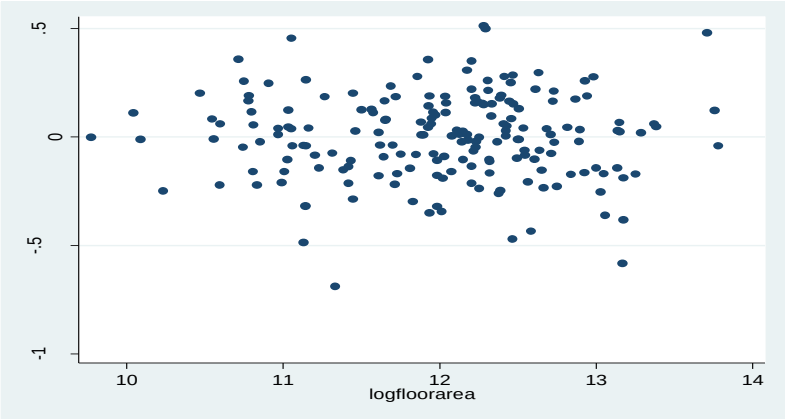
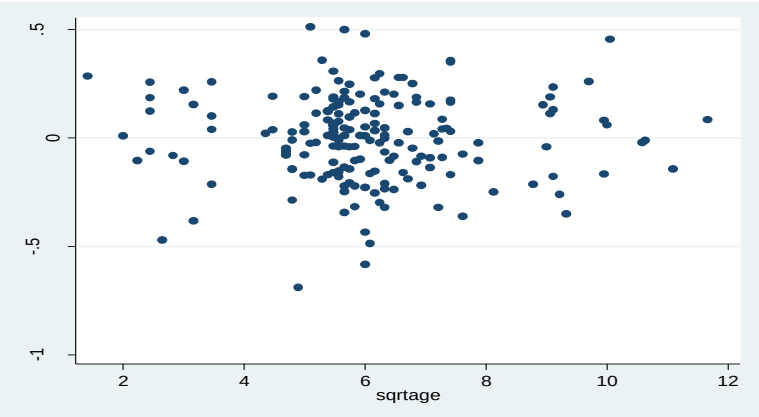


Figure 4.35 Plot of residual versus square-root of age



c- Post-Regression test for linearity

Just as we did for the residential model, we can do a final test to confirm linearity for the commercial model. The acprplots (using the residual), when plotted against our continuous variables, show that the linearity condition has been strongly met in the case of log-floorarea, and perfectly met in the case of square-root of age (very little deviation from normality in the former, and straight match in the latter case) (Fig-4.36, 4.37).

Figure 4.36 Post-Regression test for linearity

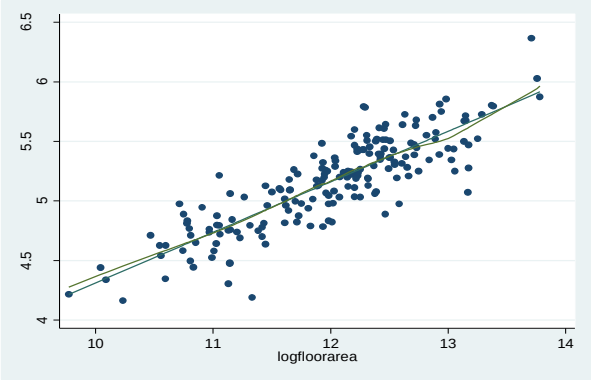
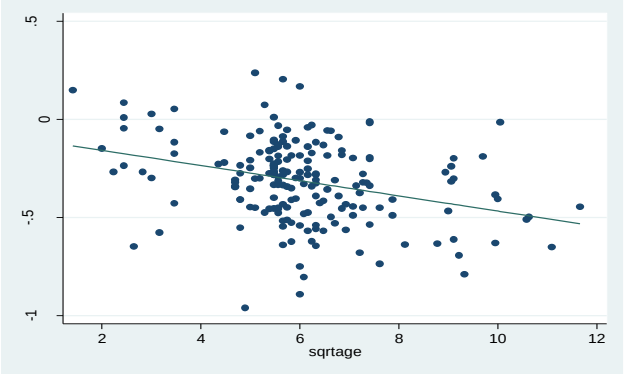


Figure 4.37 Post-Regression test for Linearity Square-root of Age



d- Multi-collinearity

Finally, we checked for multi-collinearity and found no issue. As shown below (Table-4.53), given that the variance inflation factor is below 10 in all cases, there is no issue with multi-collinearity in the model.

Table 4.53 - Test for Multi-Collinearity - Commercial

Variable	VIF	1/VIF
_Idistrict_2	3.36	0.297488
_Idistrict_1	2.90	0.344366
logfloorarea	1.39	0.719398
_Icertific~4	1.11	0.904313
_Icertific~3	1.10	0.908521
_Icertific~1	1.10	0.912173
_Icertific~2	1.09	0.917974
sqrtage	1.08	0.923718
fitness	1.08	0.924899
shopping	1.08	0.926738
Mean VIF	1.53	

4.2.4- Regression Model: Certification variables

While it is clear from above that certification does not impact the dependent variable when other variables are taken into account and controlled for, we may ask the question as to whether by itself it exerts some influence. Statistically speaking, if in a multi-variable model a variable is found to not be statistically significant, it does not mean that it has no effect. Rather, that it has no significant effect when other variables are taken into account (De Veaux et al, 2012). In order to answer this question, a simple linear model was undertaken where the dependent variable was log-evaluation and the explanatory variable was the 5-level certification variable we used above[34]. After running a preliminary model and removing one observation (outlier), we regressed log-evaluation on certification again and obtained the results below (Table-4.13). The overall linear model is significant (F-stat = 11.66, Prob > F = 0.0000). It is interesting to see that the higher levels of certification (levels 3 and 4) add positively to market-valuation as compared to non-certified properties, and this effect is significant. Furthermore, one may also note that previously we discovered a statistically-significant relationship between the office class and certification variables (see Chapter 4.2.2). Thus, we can conclude that 'higher' classes of

[34] Note: This type of model could not be carried out for the residential data since the LEED certification variables had a non-linear relationship vis-a-vis the logarithm of evaluation when divided by their levels. Also, the binary certification variable had no statistically-significant explanatory power, and so the overall model was not significant.

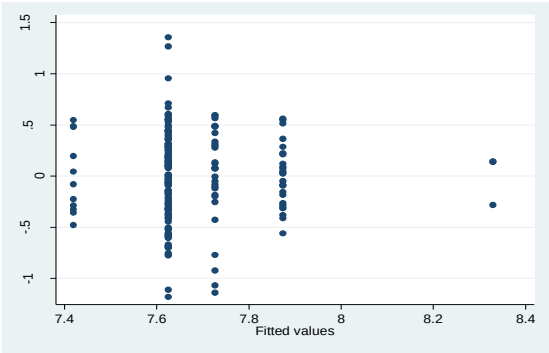
buildings (A/B) tend to have certifications, which in turn can exert some positive effects upon valuation (at the higher end). However, this is only the case when other variables have not been factored in.

The residuals for this model were normally distributed with a p-value of 0.075 which is higher than the 5% significance level (Shapiro-Wilk). Also, when the residuals were plotted against the fitted-values (predicted-values), there was no presence of auto-correlation (Fig-4.38). Thus, we can conclude that there is some positive effect of certification upon market-valuation when other explanatory variables are not taken into account. While this is an interesting result, the evidence from our multi-variable regression model is still more significant since the effects of certification upon valuation, prices, or other economic indicators should be judged on the basis of how it impacts the dependent variable in relation to other characteristics and their effects. It is still the more statistically rigorous method of testing the effects of certification, as green features are part of a system of variables which impact demand and price.

Table 4.54 Certification Variables Model Results - Commercial

Linear regression					Number of obs = 191
					F(4, 186) = 11.66
					Prob > F = 0.0000
					R-squared = 0.0892
					Root MSE = .42998
		Robust			
logevaluation	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]
_Icertifica_1	-.2051989	0.116673	-1.76	0.08	-.4353709 .0249731
_Icertifica_2	.1013406	0.098194	1.03	0.303	-.0923762 .2950573
_Icertifica_3	.2486111	0.073256	3.39	0.001	.1040917 .3931305
_Icertifica_4	.7043231	0.123433	5.71	0	.4608148 .9478314
_cons	7.624895	0.04038	188.83	0	7.545235 7.704556

Figure 4.38 Residual versus Fitted-Values



A note on 'Robust Regression'

In the robust regression model, the co-efficients are the same, but the standard errors of the co-efficients may be larger (STATA, 2014). And the t-stat may be smaller (Acock, 2012). When heteroskedasticity (of the error-term) is present, it may be more appropriate to use robust methods. Also, as a goodness of fit test, the R-square statistic is still viable (STATA, 2014).

5.0 - Logistic Model Results: Residential and Commercial

Logistic Regression- Introduction

So far in this study, we have examined 'standard' linear approaches to investigating whether there is a green premium and have been unable to find conclusive evidence for this (although, a uni-variate model for the commercial data did yield significance). For the sake of thoroughness, and to perform a cross-check of our results we can also examine a non-linear approach to modelling the relationship between market-valuation and the explanatory variables at our disposal. The most simple and appropriate non-linear modelling technique for our research question, based upon perusing the methods described in Cameron and Trivedi (2010), is logistic regression.

Logistic regression is a type of modelling technique whereby the dependent variable is a binary outcome (at least, in our case) variable takes the form of 0 or 1, depending on the 'outcome' for each observation. The most convenient way of describing the objective of logistic regression is to state that the technique tries to "model the probability of a positive outcome given a set of regressors" (STATA, 2014).

The first issue to address is the fact that clearly our dependent variable, market-valuation, is a continuous variable. Therefore, how does a binary outcome model apply in our case. The answer is that we can test whether certification affects positively the odds of market-valuation being high. Therefore, in our case, the dependent variable (for both the residential and commercial models) takes the value '0' if the value is below the 75-th percentile, and '1' if it's above the 75-th percentile.

There are a couple of other further points to note before proceeding. Logistic regression in STATA is robust in the sense that it will throw out variables and observations if they fail to conform to the statistical requirements of this modelling technique. If one or more of the independent variables perfectly predicts one of the outcomes (0-failure or 1-success), that variable will be dropped and some observations will not be used. If there are issues with co-llinearity, then those variables will be dropped as well (STATA, 2014). After several iterations, beginning with the inclusion of all the variables we listed in the descriptive statistics sections, the models illustrated below represent the final logistic models fitted. They are simple, free of the

issues mentioned above, meet the statistical tests for overall model suitability, and do confirm the conclusions reached earlier with the OLS linear models.

Residential Logistic Model

For the residential sector, we modeled the binary outcome variable 'valueseventyfive' which takes a value of 1 if the market-value for that observation is above the 75-th percentile and 0 if not. The explanatory variables are also binary (residential-city, CERT) or continuous (age, floor area, bed). For the sake of simplicity, we can examine the major variables of concern as they relate specifically to our research question. First, starting with the overall model suitability, the model is satisfactory. The probability value of the overall model (Prob>chi2) is 0 indicating that the co-efficients in the model are different from zero and have explanatory power vis-a-vis the dependent variable. In this case, once again, the certification value is not significant as the p-value (P>z) is not lower than 0.05, it is 0.10 (even though its odds ratio is greater than 1). As expected the floor area is the only statistically significant variable and the odds ratio of 1+ indicates that the odds of being in a higher value group goes up as there is a 1-unit change in this variable. The residential-city variable has the expected positive odds ratio but is just shy of being statistically significant (Table 5.1).

Table 5.1 - Logistic Regression Results - Residential Sector - 75th- percentile plus

Logistic Regression					Observations	131
					LR Chi2 (8)	55.32
Log-likelihood=					Prob> chi2	0.0000
					Pseudo R2	0.3798
Valueseventyfive	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
Residential-city	2.856386	1.620186	1.85	0.064	0.939729	8.682231
age	1.013888	0.016682	0.84	0.402	0.981713	1.047117
Floor area	1.001781	0.000445	4.01	0.000	1.000909	1.002654
cert	2.610831	1.521085	1.65	0.100	0.83342	8.178876
bed	1.332682	0.40281	0.95	0.342	0.736965	2.40994
_cons	0.000329	0.000526	-5.01	0.000	1.42E-05	0.007578

When we try the same experiment with the median value ($662,000, 50-th percentile), we get similar results as can be seen below. The model is satisfactory as the Prob > Chi2 is 0 indicating that the explanatory variables have explanatory power. Once again, all the odds ratios are above

one, but the only statistically significant variable is floor area. As before, certification is not statistically significant (Table 5.2).

Table 5.2 Logistic Regression Results - Residential Sector - 50-th percentile plus

Logistic regression				Number of obs =		131
				LR chi2(5) =		75.72
				Prob > chi2 =		0
Log likelihood = -52.906107				Pseudo R2 =		0.4171
valuefiftyplus	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
residential	2.059084	1.089037	1.37	0.172	.7302619	5.805897
age	1.016528	0.0142602	1.17	0.243	.9889597	1.044866
floorarea	1.00258	0.0005958	4.34	0.000	1.001413	1.003748
cert	1.06012	0.5837753	0.11	0.916	.3602675	3.119503
bed	1.613344	0.5141338	1.5	0.133	.863912	3.012897
_cons	.0002355	0.0004083	-4.82	0.000	7.87e-06	0.0070449

Commercial Logistic Model

The same exercise illustrated above was carried out for the commercial data-set as well. Once again, the dependent variable was valueseventyfive (a binary variable = 1, if the value was above the 75-th percentile). This variable was modelled against several explanatory variables. They are; certification (binary), floors (number of), age, floor area, core (district-binary). The results are illustrated below. Once again, the certification variable, while having a 1+ odds ratio, is not statistically significant. The floor area variable is very strong with high statistical significance and is slightly higher than 1 with respect to the odds ratio. The number of floors is also significant and with the expected odds ratio (1+, so the odds go up for higher valuation). Being in the core business district has the expected odds sign (1+) but is not statistically significant in this case. Lastly, the overall model is satisfactory, since Prob>chi2 is 0.0000 (less than 0.05) (Table-5.3).

Table 5.3 - Logistic Regression - Commercial Sector - 75th-percentile plus						
					Observations	192
					LR chi2(5)	112.60
					Prob>chi2	0.0000
Log-likelihood = -51.66					Pseudo R2	0.5215
valueseventyfive	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
certification	1.055433	0.5572026	0.1	0.919	0.3750159	2.970379
floorarea	1.00001	2.70E-06	3.77	0.000	1.000005	1.000015
floors	1.166282	0.0577789	3.1	0.002	1.058362	1.285207
age	0.9508864	0.0175843	-2.72	0.006	0.9170389	0.985983
core	2.56296	1.634969	1.48	0.14	0.7340768	8.948334
_cons	0.0057342	0.0064566	-4.58	0	0.000631	0.052108

Like we did with the residential sector, we applied the same logistic model to the median-value ($52,800,000, 50-th percentile) to assess how the odds of having a valuation higher than the median improve with respect to the same explanatory variables. Once again, our conclusions remain generally the same. In this case, the odds increase with each variable with the exception of the age variable. The only significant variables are floor area and the number of floors. The overall model is significant as the Prob>chi2 is 0.0000 (Table-5.4).

Table 5.4 - Logistic Regression - Commercial Sector - 50-th percentile plus						
Logistic regression				Number of obs =		192
				LR chi2(5) =		131.64
				Prob > chi2 =		0
Log likelihood = -67.265247				Pseudo R2 =		0.4946
fiftyplus	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
certification	1.220344	0.5707867	0.43	0.670	.4879247	3.052189
floorarea	1.000014	3.28E-06	4.36	0.000	1.000008	1.000021
floors	1.140838	0.052348	2.87	0.004	1.042716	1.248193
age	.9849045	0.0092475	-1.62	0.105	.9669454	1.003197
core	2.048133	0.9882601	1.49	0.137	.7954968	5.273244
_cons	.011411	0.009303	-5.49	0.000	.0023087	0.0564003

Therefore, the logistic models we have carried out reinforce the results we obtained earlier with linear OLS models. The certification variables were not significant in terms of the green building being in either the 50-the percentile plus nor the 75-th percentile plus valuation group.

6.0 - Vacancy Rate Analysis Results: Commercial Properties

The comparison of vacancy rates between green and non-green commercial properties has been carried out in jurisdictions outside of Canada. It is yet another metric by which we can measure the performance of green properties vis-a-vis others, and could be an indicator of the demand for green features. Vacancy rates are available for each commercial property on the Altus-Insite (2014) website. Hence, using this tool we obtained vacancy rates for as many properties as we could for our whole commercial sample. These rates were obtained as of March 20, 2014. The comparables were each re-checked again to make sure that they were still 'non-green' as of that particular date. Therefore, those whose status had changed, were taken out for this exercise. Also, vacancy rates were not provided for a number of the properties in our sample.

Taking what remained for analysis after imposing these conditions (126 properties, out of the 190 in total), we performed chi-square tests to examine if there was a relationship between certification and having a low vacancy rate (lower than the 25-th and 50-th percentile/median rate). Furthermore, we followed that analysis with two-sample means tests to see if the difference in mean vacancy rate between green and non-green properties were statistically different.

In our study, the vacancy rates were compared on a city-by-city basis. Furthermore, given that some of the non-green properties from our sample used in the regression model have over time been certified, those properties were dropped from this analysis. Therefore, those properties classified as 'green' and 'non-green' are so as of the date mentioned above. Also, given the small original sample available for the Vancouver office market, when the certification-status of those properties was re-evaluated, the remaining sample in Vancouver was too small for our analysis. Therefore, we did not be consider the Vancouver office market for this portion of our research. The methodology followed for this portion of the analysis is simple. As a first step, chi-squared tests were performed to test whether there was a relationship between green status and low-vacancy rates (lower than the median and the 25-th percentile). This analysis was followed upon by a t-test comparison of group means to ascertain whether there was a statistical difference in group mean vacancy rates (between green and non-green properties).

The analysis will now proceed to examine vacancy rates by turn in Montreal, Calgary, and Toronto.

Montreal

As can be seen below (Table-6.1), there are a total of 46 observations in Montreal. The average vacancy rate, as of March 20th, was almost 16%, with the minimal at 1.8% and the maximum at 67%. In the sample there are 19 non-green commercial properties to 27 green properties. The 25-percentile is 5.6%, while the median is 11.1%.

Table 6.1 - Descriptive Statistics -Vacancy Rate - Montreal					
Variable	Observations	Mean	Std. Deviation	Minimum	Maximum
Vacancy	46	15.77	15.22	1.8	67

In order to perform the chi-square tests, the properties were divided into four major categories, green and non-green, and those with a vacancy rate lower than the 25th-percentile (and the median - 50th percentile). The results of those tests are illustrated below:

Table 6.2 Chi-Square Results - Montreal						
Green	Above 25-percentile	Below 25-percentile	Total	Above Median	Below Median	Total
Non-green	15 (78.95)	4 (21.05)	19	12 (63.2)	7 (36.8)	19
Green	19 (70.37)	8 (29.63)	27	11 (40.7)	16 (59.3)	27
Total	34 (73.91)	12 (26.09)	46	23 (50.0)	23 (50.0)	46
Pearson Chi-square	Chi2(1)=0.425, Pr=0.514			Chi2(1) = 2.2417, Pr=0.134		

The chi-square results above confirmed that there is no statistically significant relationship between vacancy rates and green certification, even though the majority of properties below the 25- and 50-th percentile vacancy rates were green properties. This is because the chi-square values of 0.425 and 2.2417 are not high enough to reject the null-hypothesis (that the difference between green and non-green is insignificant) (Acock, 2012). What we can say is that BOMA-BEST properties are more likely to have lower vacancy rates, but the difference is not statistically significant

Two sample test of group means - Montreal

The second part of our analysis was to test whether there is a statistically significant difference in the mean vacancy rates. Table-6.3 below once again confirms the lack of a green premium (in this case, a statistically significant lower 'green' mean vacancy rate).

The null hypothesis in this case is that the means of the two groups (green and non-green) are the same. In order to test for this hypothesis, we carried out a two-sample t-test, which yields a t-value of 0.9810. Using the standard 5% significance level, we cannot reject the null-hypothesis that the two means are the same (even though the mean vacancy rate for green properties at almost 14% compared to non-green is lower in our sample).

Table 6.3 Comparison of Group means - Montreal

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
0 (non-green)	19	18.4	4.046159	17.6368	9.899335	26.90066
1 (green)	27	13.92593	2.561937	13.31222	8.659789	19.19206
combined	46	15.77391	2.244677	15.22414	11.2529	20.29492
diff		4.474074	4.560733		-4.71748	13.66563
Diff = mean(0)- mean (1)					t = 0.9810	
Ho : diff = 0					Degrees of freedom = 44	
Ha: diff < 0		Ha : diff !=0			Ha: diff> 0	
Pr (T < t) = 0.8340		Pr (|T| > |t|) = 0.3320			Pr (T > t) = 0.1660	

Calgary

For the City of Calgary, there are a total of 45 properties in our sample (Table-6.4). The mean vacancy rate is 17.48%, and the range of vacancy rates is quite large with the minimum being 1% and the maximum being 91%. The 25th-percentile is 5%, while the median is 10.3%.

Table 6.4 - Descriptive Statistics - Vacancy-Rate - Calgary

	Observations	Mean	Std. Deviation	Minimum	Maximum
Vacancy	45	17.48	19.13	1	91

The results of the chi-square tests are illustrated below (Table-6.5). In this case, once again, a statistical relationship between the vacancy rates and green building certification could not be established (low values of chi-square, we cannot rule out null-hypothesis). The difference here as compared to the case with Montreal, is that there are now more non-green properties (as compared to green) who fall in the below 25th-percentile category, a reversal of the previous

case. Again, we can say that green buildings are more likely to have a lower vacancy rate, however, this difference is not statistically significant.

Table 6.5 Chi-Square Tests - Vacancy-Rate - Calgary						
	Above 25-percentile	Below 25-percentile	Total	Above median	Below median	Total
Non-green	21 (77.78)	6 (22.22)	27	15 (55.56)	12 (44.44)	27
Green	13 (72.22)	5 (27.78)	18	8 (44.44)	10 (55.56)	18
Total	34 (75.56)	11 (24.44)	45	23 (51.11)	22 (48.89)	45
Pearson chi-square	Chi2 (1) = 0.1805, Pr = 0.671			Chi2 (1) = 0.5336, Pr = 0.465		

Two sample test of means - Calgary

We repeated the same two sample test of means carried out earlier to see if the means of green and non-green are statistically different. Once again, the green mean vacancy rate of 12% is much lower than the non-green rate of almost 21%. However, with a t-value of only 1.5, it still does not meet the threshold of the two-tailed (5% - significance) test. Hence, we cannot again reject the null hypothesis that the two group means are the same (Table-6.6).

Table 6.6 - Comparison of Group means - Vacancy-rates- Calgary						
Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
0 (non-green)	27	20.93333	4.408713	22.90835	11.87109	29.99557
1 (green)	18	12.30556	2.327015	9.872688	7.395983	17.21513
combined	45	17.48222	2.852035	19.13203	11.73432	23.23012
diff		8.627778	5.740136		-2.948309	20.20386
Diff = mean (0) - mean (1)					t = 1.5031	
Ho : diff = 0					Degrees of freedom = 43	
Ha: diff < 0		Ha : diff ! = 0			Ha: diff > 0	
Pr (T < t) = 0.9299		Pr (|T| > |t|) = 0.1401			Pr (T > t) = 0.0701	

Toronto

For the city of Toronto there are 35 commercial properties available for study. The mean vacancy rate is 11.2%, and the minimum and maximum rates are 1% and 84% respectively. The 25th-percentile is 2.9%, and the median is 5.9% (Table-6.7)

Table 6.7 - Descriptive Statistics - Vacancy-rate - Toronto					
	Observations	Mean	Std. Deviation	Minimum	Maximum
Vacancy	35	11.19	15.33	1	84

The results of the chi-square tests are illustrated below (Table-6.8). As we can see, with respect to properties which are below both the 25th and median percentile rates, green properties fare well and comprise the majority of properties in this group. However, once again, the chi-square tests confirm that there is no relationship between low vacancy rates and certification (low chi-square values, therefore we cannot rule out null hypothesis). We can say that green buildings are more likely to have lower vacancy rates, but this difference is not statistically significant.

Table 6.8 - Chi-Square tests - Vacancy-rates- Toronto						
	Above 25-percentile	Below 25-percentile	Total	Above Median	Below Median	Total
Non-green	13 (86.67)	2 (13.33)	15	9 (60.00)	6 (40.00)	15
Green	14 (70.00)	6 (30.00)	20	9 (45.00)	11 (55.00)	20
Total	27 (77.14)	8 (22.86)		18 (51.42)	17 (48.57)	35
Pearson chi-squared	Chi2 (1) = 1.3503, Pr = 0.245			Chi2 (1) = 0.7721, Pr = 0.380		

Two sample test of group means - Toronto

We compared the mean vacancy rate of the green group with that of the non-green group. In this case, the mean vacancy rate of the green group is slightly higher (12% to 10.4%). However, once again, this difference is not statistically significant, as the t-value is -0.26 and does not meet the threshold of the 5% significance level for a two-tailed test (Table-6.9). Therefore, we cannot reject the null hypothesis that the two group means are the same.

Table 6.9- Comparison of Group Means - Toronto						
Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
0 (non-green)	15	10.39333	2.333186	9.036392	5.389146	15.39752
1 (green)	20	11.78	4.238325	18.95437	2.909084	20.65092
combined	35	11.18571	2.590507	15.32564	5.921171	16.45026
diff		-1.38667	5.30794		-12.1858	9.412418
Diff = mean (0) - mean (1)					t = -0.2612	
Ho : diff = 0					Degrees of freedom = 33	
Ha: diff < 0		Ha : diff ! = 0			Ha: diff > 0	
Pr (T < t) = 0.3978		Pr (|T| > |t|) = 0.7955			Pr (T > t) = 0.6022	

To sum up, on the whole, we can conclude that green properties tend to have lower vacancy rates than their non-green counter-parts. However, our analysis demonstrates in those cases when this was confirmed the differences were not statistically-significant. We must also note that this conclusion is restricted to the current sample available for our study, and does not necessarily reflect the population dynamics of the commercial sector.

7.0 - Paired-Analysis Results: Ontario Residential Properties

7.1 - Paired Analysis - Theoretical Background

In the appraisal profession, there are three approaches available for valuators, which often serve as a check against the results obtained by the other. They are the cost-method, the direct-comparison method, and the income approach method (Appraisal Institute of Canada[35], 2011). Finally, the direct-comparison method allows the valuator to estimate the value of a property by comparing the subject property (to be valued) to similar properties that have been sold in the same particular neighborhood during a particular time-period (ibid, 2011).

The paired-comparison method (under the direct-comparison approach) involves comparing two sets of information, isolating a single characteristic as the subject of adjustment, and determining that characteristic's impact on sale price (provided they are more or less equal on other variables) (AIC, 2010, Pg. 5.13). This is an important aspect of the technique and applies directly to the work we are undertaking in our research. We have a limited number of green properties whose selling prices we have obtained through valuation agencies, and so we can compare these 'subject' green properties to non-green comparables, adjusting the selling prices of the comparables towards the subject properties, and then evaluating if there is a price difference due to 'green' features (certification). Essentially, in this thesis, we used a standard appraisal technique used in modern real-estate analysis, and modified it for our own ends. Therefore, now we must discuss what paired-analysis means in our context, justify, and explain some of the changes to the technique we implemented.

In conventional appraisal analysis using the paired-analysis technique, the subject and comparable properties are adjusted or "equalised" on the basis of ten variables (ibid, 2010). They are explained in Table 7.1 below. In our case, we do not possess information about the first four items and the non-realty items. As such, they will not form the basis for adjustment[36]. Information such as these with regard to a sale/purchase of a home is confidential and contacting

[35] Appraisal Institute of Canada = AIC.
[36] One can recognize this is a limitation of our study, as sometime these items do influence price through the willingness either party to buy and/or sell

home-owners will violate the terms of agreement we are obliged to follow as part of the data purchases we have made (see annex). Also, given that the subject and comparable properties, in all cases, come from the same neighborhood, adjustments for location and zoning, are likely not required[37] (items 6 & 9). Lastly, given that these are residential properties, there is no need to adjust for Item 8 (economic characteristics).

Table 7.1 Paired-Analysis - Order of Adjustments	
Order - Elements of Comparison	**Rationale**
1- Rights Conveyed	Property rights greater or less than subject
2- Financing Terms	Favourable financing distorts original price
3- Conditions of sale (motivation)	Undue pressure at time of sale
4- Expenditures made immediately after purchase	Monies to be spent by the purchaser
5- Market Conditions (Time)	Reflect changes in market over time
6- Location	The impact on price because of different locations
7- Physical Characteristics	Differences in size, age, condition, etc.
8- Economic Characteristics	Aspects of a property that affect its net operating income
9- Use/Zoning	Factors that result in differing property utility
10- Non-Realty Items	Personal items, business concerns

Source: AIC, 2010.

Thus, we are left with two points for comparison and adjustment, time and physical characteristics. The time adjustment comes about since sometimes the comparable properties were sold in a different time period. Hence, in that case, we need to adjust the price of the comparable in a manner that reflects how the market-values (i.e. prices) have moved (or not) in the intervening period. Usually, if the comparable was sold within the month, a time adjustment is not necessary (ibid, 2010). Often, time-adjustments are made through a combination of paired-sales, and market-statistics. Hence, the analyst is required to examine two similar properties from the same neighborhood which were sold in different time-periods, the difference between their prices reflects the market (time) adjustment. One may also use price statistics (average prices, median prices, the price index, etc.) to undertake this analysis. The key is to try and use neighborhood-level information to the greatest extent possible (ibid, 2010).

[37] NOTE: This point is supported by the fact that the comparable for Subject 1 (North York) is located 650 meters from the subject property and neither are located along a major artery, nor are they 'corner' lots. The same is true for Subject 2 and its comparable (Guelph). Lastly, Subject 3 is 1 kilometer away from Comparable 1 and 750 meters away from Comparable 2, none of the properties are located along a major artery, nor are they corner lots. However, Comparable 1 is located at the edge of Milton's residential development. Therefore, if this is a limitation of the analysis, then it can be considered minimal.

Perhaps the most influential adjustments we will be making concern the ones connected to differences in physical characteristics. Again, we do not possess detailed data about the condition of the homes, which would require an actual inspection. And so we cannot make adjustments for factors such as fitments, quality of construction, appliances, etc. Although the subjects and comparables are of similar age and located in the same neighborhood, we can recognize this unknown as a limitation of our study. How important this limitation is depends on the amount of work the owner may have undertaken after purchase. However, generally age can be considered to be a good indicator of quality. In that respect, the properties are similar as there is a one year difference in the ages of Subjects 1, 2, and 3 and their comparables (with the exception of Comparable 2 for Subject 3, in which case the difference is two years). Also, these properties have been constructed relatively recently, with the oldest comparables constructed in 2008 (Comparable for Guelph, and Comparable 2 for Milton). As such, it is likely that minimal modifications have been made to these properties, giving rise to major differences in quality. Lastly, it is generally common practice for developers to construct similar properties in a particular neighborhood. Therefore, we can conclude that the limitation stated above is likely minimal in our analysis.

Lastly, we mentioned earlier that the paired-analysis in our case will be modified to suit our needs. Normally, for making adjustments to individual variables (including time), at least two sets of paired sales are used (separate from the subject and comparables). For example, if we are making an adjustment for the number of washrooms, then we would examine two pairs of properties (which are equal on other measures) and examine the price differential, which would be an indication of the value of an extra bathroom. The comparable would then be adjusted accordingly towards the subject property (UBC, 2010).

However, a more statistically rigorous method for making the adjustment involves using regression analysis which allows us to map the average relationship between the selling (or listed) prices and the particular variable of interest over a much larger sample, using a more advanced statistical approach. This is the approach we have opted for in our study. Also, simply using paired sales for adjusting comparables may be an ambiguous exercise. This is because there is no firm statistical foundation upon which the adjustments are made. They could be

anomalies, outliers, etc. We will now discuss in more detail the data sources and methods we used.

7.2 - Paired-Analysis: Data source and adjustments

From the outset, from our final sample of 130 residential properties (used for the hedonic model), we needed to impose a couple of restrictions in order to finalise the sample required for paired-analysis. First, with respect to the subject property, it was necessary to have the historical selling prices listed. Also, for the subject properties which do have selling prices listed, it was crucial that the selling date occur after the certification was achieved. Secondly, for the comparable properties (those to which the subject sale price would be compared), the sale price must be present and the time-gap between the subject sale price and comparable sale price must be within two and a half years. Imposing these basic restrictions limits our sample to three subject-comparable pairs in Ontario, and none in British Columbia.

Data Origins

The properties we'll be examining throughout this exercise are part of the larger sample constructed for the earlier regression exercise. First, a time-limit of 2.5 years (between date of subject and comparable sale) was imposed in order to be able to perform at least three paired-analysis comparisons. Imposing a limit of less than 2 years would have only allowed two paired comparisons. On the other hand, allowing the time adjustment to go beyond this time-frame may be problematic. This is because it is preferable to keep the time-gap as narrow as possible given that market-conditions and the factors which influence them vary over time. Hence, adjusting for a time gap of several years is not advisable since changes could have occurred to the comparable property and/or the real-estate market (economic events, changes in market-preferences, laws, etc.) (Appraisal Institute of Canada, 2010). Hence, the chosen time-limit was essentially a compromise between the need for conducting more than just two comparisons and the demands of result validity. Furthermore, when we examined the data available to us, this became more apparent.

In the case of Ontario, there were thirteen subject properties whose selling prices were listed. Out of this group, two properties were certified post the date of sale and so were ineligible for this exercise. Furthermore, there were seven subject properties whose sale dates were too 'far' from

the sale date of their nearest comparable (the time-differences ranged from 6 years and 4 months to 32 years), making those properties ineligible. That left 4 properties in Ontario which were eligible. Out of this group, one subject property did not have a finished basement, while the closest comparable (with a sale date gap of just over two years) did have a finished basement. This presented a problem with respect to the adjustment required for the comparable property, since details on whether a basement was finished and the size of the finished unit on the MLS (Realtor.ca) website is left up to the discretion of the real-estate agent and was missing for many of the properties listed. Given that our adjustments needed to be based on market-data (using uni-variate regression models), we could not perform the adjustment required in this case with the same statistical rigor that was used for the other paired-analyses. As such, the decision was made to conduct the paired-analyses with just the three remaining properties in Ontario.

Lastly, in the case of British Columbia, there were nine subject properties with sale prices listed. Out of this group, 3 properties were certified after the sale had already taken place. The other eligible comparable properties were sold with a time gap of at least 3 years and 3 months from when their subject properties were sold. Hence, all the properties in British Columbia were ineligible for comparison.

Data Adjustments

In the case of Ontario, there are two one-on-one comparisons and a third one-on-two (properties) comparison. The comparable for the first pair was adjusted for time towards the subject property using average home sale prices (detached) provided by the Toronto Real-Estate Board (2014). The second pair was be adjusted for lot-size, living-area, and time, using regression analysis to determine the adjustments needed for the first two variables. The CMHC's (2014) Housing Info Monthly data on the percentage changes in the median sale prices of absorbed detached/semi-detached units were used for the time adjustment[38]. In this case, the time adjustment is equal to the percent change in selling prices between the two time-periods.

The regression analyses (for lot-size and living-area) incorporated a simple linear uni-variate model with price as the dependent variable and lot-size/living area (square-footage) as the

[38] NOTE: There are some limitations to utilising this method in the context of paired-analysis, as this is not neighborhood-level data. However, it likely provides a good approximation of it.

explanatory variable. The co-efficient indicated the adjustment needed in the price (of the comparables) for a one-unit change in lot-size/square footage.

For the final paired-analysis exercise, no time change was needed (as the time-difference in sales was one month), and the adjustments were based upon living area (square-footage) and lot-size, once again regression analysis was used to find the adjustment needed. Lastly, for all the regression models, the data on listed selling prices (on offer) and the lot-size and living area (square footage) were obtained from the Multiple Listing Service (realtor.ca, 2014) for each locality using set parameters which will be described in the results chapter.

7.3 - Paired Analysis: Exercises

7.3.1- Subject 1 - Toronto

The first subject property is a 2-storey detached single-home in the North York neighborhood of Toronto. It was built in 2010, has a finished basement, four bedrooms, five bathrooms. It is a moderately sized home comprising of almost 2400 square footage of living space, while the lot area is just over 4000 square feet. The second subject property is another 2-storey single-detached home located in the southern end of the City of Guelph, built in 2009. It has four bedrooms, three bathrooms, a living area of over 2800 square feet, and a lot of 5300 square feet. Lastly, the third subject property is a 2-storey single-detached home, built in 2010. It consists of almost 2700 square feet of living space with four bathrooms and bedrooms, with a lot size of just under 3500 square feet.

Subject 1 is located in the North York neighborhood of Toronto. The adjustments necessary in this case were for time and lot-size. Although there is a slight difference in living-area size (square-footage), it was too small to require an adjustment.

Table 7.2 - Description of Subject and Comparable Property - Toronto

	City	Description	Year	Basement	Footage	Storeys	Bedrooms	Bathrooms	Lot	Sale	Date
Subject 1	Toronto	detached	2010	Finished	2363	2	4	5	4004	1,628,000	2013-06
Comparable	Toronto	detached	2009	Finished	2400	2	4	5	3465	1,441,900	2012-08

As a first step we needed to address an issue with respect to the lot adjustment. Using the listings in the Canadian Multiple Listing Service (Realtor.ca), we first tried to plot a relationship between

price and lot for almost a hundred and twenty properties to see if a clear positive relationship could be discerned. This exercise was repeated twice (in March, 2014 with over 30 properties, and in June, 2014 with 90 properties - from the North York area). When we calculated the correlations between the price and the lot variables no statistically significant relationship could be found. The Pearson-correlation statistic is 0.0564, and not statistically significant (p-value=0.6039) for the 90 properties evaluated in June (and -0.07, non significant for March 2014- 30 properties). For this reason, given that a clear statistical relationship cannot be established, a lot adjustment will not be undertaken for the subject property in Toronto.

Time-Adjustment: Toronto

We were able to carry out an adjustment for time for the comparable property using basic statistics available from the Toronto Real-Estate Board (TREB). The TREB (2014) provides price indices at the neighborhood level for different property types. For the North York (Bay-view) Neighborhood where our subject and comparable properties are located, the single family detached home price index increased 2.35% over the course of the 10 months (between the sale of the subject property and the comparable). Therefore, we adjusted the selling price of the comparable upward by 2.4%. The comparable was sold for $1,441,900, adding 2.4% to this price lead to an 'adjusted' price of $1,475,785. This price, compared to the subject property sale price of $1,628,000 in the same neighborhood is much less, and could be evidence of a 'green' premium. However, we did not carry out an adjustment for lot-size, so can only be cautious about this finding.

7.3.3- Subject 2- Guelph

The Subject property number 2 is located in the southern part of the City of Guelph. The adjustments needed for the comparable were for the living area, lot size, and time. Each of these adjustments will be discussed in turn.

Table 7.3 - Description of Subject and Comparable Property - Guelph

	City	Type	Year	Basement	Living Area	Storey	Bed	Bath	Lot	Sale	Date
Subject 2	Guelph	detached	2009	Unfinished	2820	2	4	3	5312	540,000	2010-08
Comparable	Guelph	detached	2008	Unfinished	3050	2	4	3	4588	562,000	2012-10

Lot-size: Guelph

Once again, using MLS statistics we created a data-base comprising 89 observations of listed selling prices and the associated lot-sizes of each of those properties. The search parameters used were; 'single-detached homes, 2 storeys, with 4 bedrooms, 3 bathrooms' for all of Guelph. When we calculated the Pearson correlation estimate between price and lot-size, we obtained a moderate and statistically significant value of 0.3476 (p-value = 0.0008). Given that a linear relationship existed between the two variables, we proceeded to remove twenty 'outliers' from the sample such that a robust linear model could be established. The results are described below (Table-7.4). We can see that our model has strong overall explanatory power as the F-stat is 51.3 (there is a statistically significant relationship between lot-size and home price), and 34% of the variation in price can be explained by changes in the lot-size. Furthermore, on average, a 1 (square-foot) unit change in lot-size is associated with a $24 change in house price (and our co-efficient is significant).

Table 7.4 -Regression Results - Guelph - Lot-Size

Linear Regression					Number of obs	69
					F(1, 67)	51.3
					Prob > F	0
					R-squared	0.3378
					Root MSE	78916
		Robust				
price	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
lot	24.23827	3.384159	7.16	0	17.48346	30.99308
_cons	406507.3	21748.66	18.69	0	363096.8	449917.8

Further diagnostic tests confirmed that our model is sound, as there is no evidence of auto-correlation (plot of the residuals against the fitted-values, Fig-7.1). Since we used the 'robust' regression option, hetero-skedasticity is not an issue as these co-efficients were estimated without that assumption. Also, tests for dependent variable and error normality were met comfortably (Table-7.5, 7.6).

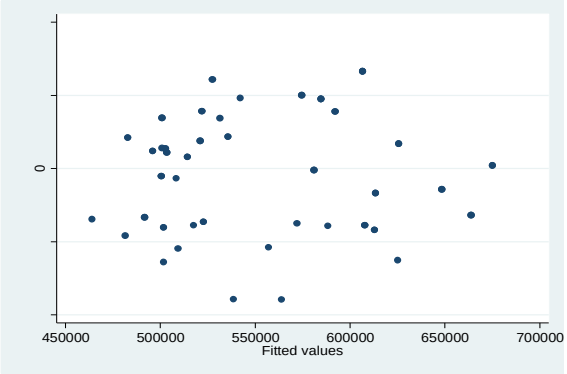
Table 7.5 - Test for Normality - Errors

Variable	Obs	W	V	z	Prob>z
e	69	0.97339	1.619	1.047	0.14759

Table 7.6 - Test for Normality - Price

Shapiro-Wilk W test	for normal	data		
Variable	Obs W	V	z	Prob>z
price	69 0.98203	1.093	0.194	0.42303

Figure 7.1 Residuals versus Fitted Valued - Lot-Size - Guelph



Therefore, if one extra square footage change brings about a change of $24.24 to the listed selling-price, then an upward change of 724 square feet implies an adjustment of $17,376 ($24.24 x 724) to the selling price of the comparable.

Living Area (footage): Guelph

For measuring the relationship between home selling price and living area, once again, the Multiple Listing Service and the same search criteria described above was utilised. As such, we were able to obtain 85 properties, their listed selling prices, and the total square footage of the home. As a start, we obtained the Pearson correlation statistic and found that there is a strong linear relationship measured at 0.6367 (p-value = 0.0000). Given this confirmation, we proceeded to remove 11 'outliers' to improve our linear model. We then modelled the relationship between price and square-footage.

As we can see (Table-7.7), our model shows a very strong statistical relationship between price and home square footage, our F-stat is 258, and the R-square is 72%. The footage variable has a high t-stat and is statistically significant. We can say that for every 1 square foot change in the size of a home the price changes on average by $252. When we plotted the residuals against the fitted-values of price, we found no issues with auto-correlation (Fig-7.2). Also, given that we used the robust regression option, we can ignore the issue of hetero-skedasticity. Lastly, tests for dependent variable and error normality were met comfortably (Table-7.8, 7.9).

Table 7.7 Regression Results - Footage - Guelph

Linear regression					Number of obs	74
					F(1, 72)	258.28
					Prob > F	0
					R-squared	0.7193
					Root MSE	51011
		Robust				
price	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
footage	252.2927	15.69855	16.1	0	220.9983	283.5872
_cons	-37211.84	37186.75	-1	0.32	-111342.3	36918.59

Figure 7.2 - Residuals versus Fitted Values- Footage- Guelph

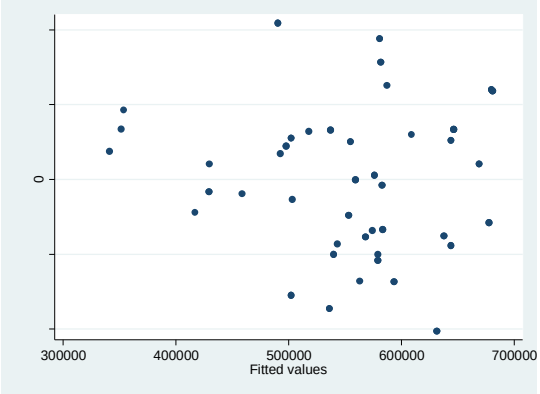


Table 7.8 - Test for Error normality- Guelph

Variable	Obs	W	V	z	Prob>z
e	74	0.98678	0.851	-0.351	0.63709

Table 7.9 - Test for Normality - Price

Variable	Obs	W	V	z	Prob>z
price	74	0.98503	0.964	-0.080	0.53207

Therefore, in the case of the living area (square footage), given that our comparable is a larger house than the subject property, the comparable must be adjusted downwards. Thus, if a change in one square foot leads to a change of $252.30 dollars, then a downward adjustment of 230 square feet implies a negative adjustment of $58,029 for our comparable.

Note: *Correlation between footage and lot*

We also found that there was no statistical relationship at the 5%-level between lot-size and footage, hence we have greater security that there are no issues with double-counting the influence of either variable.

	Lot	Footage
Lot	1.000	
Footage	-0.0471 (0.6686)	1.000

Time Adjustment: Guelph

The time adjustment for the Guelph comparable properties relied upon median price data for newly completed and absorbed single-detached dwelling provided by the Canada Mortgage and Housing Corporation (2013) through their publication Housing Info Monthly. Their figures point out that going 'backward' from October 2012 (sale date of comparable) to August 2010 (sale date of subject), the median sale price for single-detached dwellings decreased by 10.6% (or 0.44% per month on average). Hence, that is the time adjustment we imposed upon our comparable property.

7.3.3- Subject 3- Milton

Subject property number 3 is located in the western end of the Township of Milton (outside of Toronto). Given that the comparable properties were sold within a month of the sale of the subject property, no time adjustments are necessary. Therefore, the comparables in this case was adjusted for the lot-size and living area.

Table 7.11 - Description of Subject and Comparable properties - Milton											
	City	Type	Year	Basement	Living Area	Storey	Bed	Bath	Lot	Sale	Date
Subject 3	Milton	detached	2010	Unfinished	2680	2	4	4	3481	620,000	2014-02
Comparable 1	Milton	detached	2009	Unfinished	2650	2	4	4	4731	685,000	2014-01
Comparable 2	Milton	detached	2008	Unfinished	2600	2	4	4	4330	619,000	2014-01

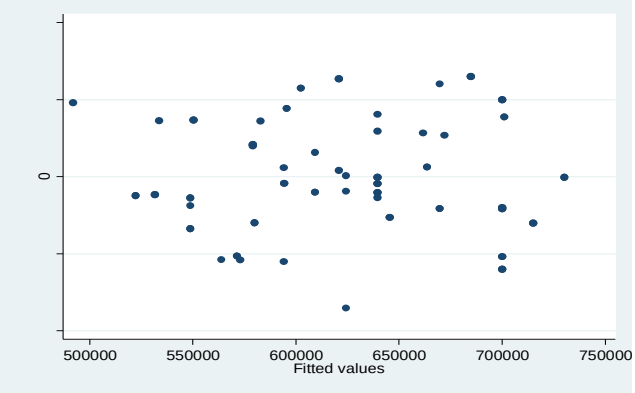
Living Area (footage): Milton

For adjustment, we used once again properties listed in the Multiple Listing Service website. By inputting the parameters '2 story, single-detached, 4 bedrooms, 4 bathrooms, and the price range 500,000-1,000,000', we obtained a sample of 84 properties for the Milton township area[39]. As before, the first step was to test the strength of the linear relationship between the two variables. This test revealed a strong relationship of 0.7399 (p-value = 0.0000) that is statistically significant. Hence, we proceeded to model this relationship with a linear regression model. As a first step, 8 outliers were removed from the sample to improve the strength of the model. The results of the model are shown below (Table-7.12). As expected, we obtained a very strong relationship between price and square footage. The F-stat is a high 209, while footage explains 73% of the variation in listed selling prices. The footage variable is also statistically significant at the 5% level. It shows that a 1 square-foot change in the size of a home is associated, on average, with a $151 change in the listed selling price. The graph below plots the residuals versus the fitted values of price, and it indicated that we did not have any issues with auto-correlation (Fig-7.3). Once again, due to our use of robust regression, we did not assume homo-skedasticity of the residuals. Lastly, tests for dependent variable and error normality were met comfortably (Table-7.13, 7.14).

[39] It should be noted that there is a risk that real-estate agents overstate home selling prices (compared to what they are actually worth in the market). We will acknowledge this as a limitation of the study.

Table 7.12 - Regression Results - Footage - Milton						
Linear regression					Number of obs	76
					F(1, 74)	209.17
					Prob > F	0
					R-squared	0.7301
					Root MSE	36399
		Robust				
price	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
footage	151.2053	10.45489	14.46	0	130.3735	172.0371
_cons	246337	26017.83	9.47	0	194495.3	298178.6

Figure 7.3 Residuals versus fitted-values - Footage - Milton



7.13- Normality of errors - Milton- Footage

Variable	Obs W	V	z	Prob>z
e	76 0.96863	2.065	1.584	0.05661

7.14 - Normality of Price - Milton

Variable	Obs W	V	z	Prob>z
price	76 0.97034	1.952	1.461	0.07199

Lastly, given that a one square foot change in living area leads to a change in the selling price of $151, then upward additions of 30 and 80 square feet to comparables 1 and 2 respectively leads

to an upward selling price adjustment of $4530 ($151 x 30) for comparable 1 and $12,080 ($151 x 80) for comparable 2[40].

Lot-Size: Milton

The second variable which required adjustment was lot-size. As before, we utilised the Multiple Listing service website to obtain market-data. Our search parameters to obtain the data was similar (2 storey, single-detached, 4-bed, 4-bath) to what we did earlier, except the price range was broadened to include properties in the $400,000 to $1,000,000 range. As such, we obtained a larger sample of 109 properties[41]. When outliers were removed, we had a remaining sample of ninety-four properties for analysis. The Pearson linear correlation for this relationship was moderately-strong (0.3966) and statistically significant (p-value = 0.0001). The results table below (Table-7.15) show a strong positive relationship between listed selling-price and lot-size (the F-stat is 20.27, Prob > F =0). The lot-size explains 16% of the variation in listed selling-price, and is statistically significant at the 5% level. The model shows that a one square-foot change in lot-size results in, on average, a $55 dollar change in the listed selling-price. The graph below plots the residuals versus the fitted values, which revealed that were are no issues with auto-correlation (Fig-7.4). Since we used robust regression, we did not assume homo-skedasticity in our model. Lastly, tests for dependent and error variable normality were met comfortably (Table-7.16, 7.17).

Table 7.15 - Regression Results - Lot-size - Milton

Linear Regression					Number of obs	94
					F(1, 92)	20.27
					Prob > F	0
					R-squared	0.1573
					Root MSE	70718
		Robust				
price	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
lot	55.18561	12.25639	4.5	0	30.84336	79.52786
_cons	416645.7	44000.32	9.47	0	329257.3	504034.1

[40] For Milton, the footage and lot did show a weak but statistically-significant (Pearson) linear relationship of 0.2597 (significant at the 5%-level). However, this weak relationship is unlikely to affect the robustness of our co-efficients greatly.

[41] This was done due to previous issues with respect to finding a relationship between price and lot-size, as in the case of Toronto.

Figure 7.4 - Residual versus fitted-values - Lot-size - Milton

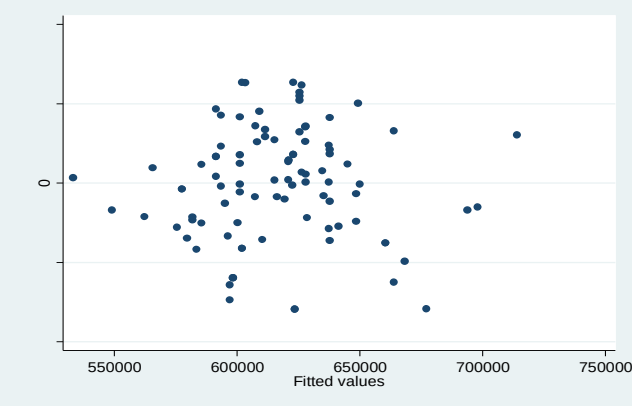


Table 7.16 - Error normality - Lot-size - Milton

Variable	Obs	W	V	z	Prob>z
e	94	0.98109	1.483	0.871	0.19179

Table 7.17- Test for normality- Price- Milton

Variable	Obs	W	V	z	Prob>z
price	94	0.98345	1.298	0.577	0.28211

Lastly, with respect to our adjustments to the comparables for lot-size, Comparable 1 has a lot that is 1250 square feet larger, which translates to an adjustment downward of $68,988 (1250 x $55.19). The Comparable 2 has a lot that is 849 square-feet larger. That also implies an adjustment downward of $46,856 (849 x $55.19).

Paired Adjustments

The appraisal literature states that the reconciliation process whereby the final adjustments are made to the comparables should be done in a particular order. This is to ensure that the adjusted prices of the comparables reflects market-value accurately (AIC, 2010). Table-7.1 illustrates the process to be usually followed.

Therefore, using the guide above our order of adjustment (for subject properties 2 & 3) will be time, followed by footage and lot. The final adjustments table below (Table-7.19) summarizes the results of our paired analysis work. As we can see, once again, we still cannot confirm

conclusively that a 'green premium' exists, as not all the subject prices were higher than the prices of their comparables.

When the comparable in Toronto was adjusted for time, the sale price was much lower than that of the subject property. Hence, this may be some evidence in support of green features, at least in the north Toronto residential market (however, we did not adjust for lot-size).

And we see similar evidence in Guelph when the adjustments are completed. The comparable was about $80,000 lower in price as compared to the subject green property. When we consider the Milton residential market, the first comparable property when adjusted had almost the same price as the subject property. The second comparable after adjustment was over $35,000 lower in price. Therefore, once again, we are unable to make any firm conclusions as to whether there is a green premium with respect to selling prices. However, these results are somewhat more positive than what we achieved with the hedonic model exercise.

Table 7.19 - Paired Analysis - Adjustments

Subject Price	**Comparable 1**	**Comparable 2**
Subject 1: Price ($1,628,000)	$1,441,900	
	Time (+2.4%)	
	Final : $1,475,785	
Subject 2: Price ($540,000)	$562,000	
	Time (-10.6%)	
	- $58,029 (Living area)	
	+ $17,376 (Lot area)	
	Final: $461,775	
Subject 3: Price ($620,000)	$685,000	$619,000
	+ $4530 (Living area)	+ $12,080 (Living area)
	- $68,988 (Lot-size)	- $46,856 (Lot-size)
	Final: $620,542	**Final: $584,224**

8.0- Discussion

The results we have presented from all our analyses do not provide conclusive evidence for the existence of a green premium for the variables and markets studied. Our residential hedonic model tested a binary certification variable which was found to be non-significant. The commercial hedonic model tested a multi-level certification variable which did exert a positive and statistically-significant effect (for only Level-3), however, given that this result stands alone when compared to other levels, we reach the same pessimistic conclusion. When we carried out a comparison of commercial vacancy rates in four key office markets, we did show that green buildings have lower vacancy rates, however, this difference was not statistically significant. Hence, no green premium could be found with respect to that metric either for our limited sample. Lastly, our paired-analysis of three green properties in Southern Ontario did not lead to evidence of a green premium for *all* cases.

If these results are compared to the general hedonic literature (mostly U.S.-based), the one hedonic study which included the same dependent variable as us (Dermisi, 2009) reached inconclusive results as well (the certification variable was both positive and negative for a series of models). Therefore, while we cannot assert that our results are an anomaly (given the lack of exactly comparable studies) we can, however, examine factors that could have contributed to our "negative" results.

Specifically, we will look at four major factors that could account for our results. They are, limitations related to valuation methodology in Canada, the role of the policy environment in Canada, the state of real-estate client-preferences, and possible limitations related to our study methodology and data-collection. These discussions, combined with the points raised in earlier chapters will also enable us to provide recommendations for the next-generation of academic and industry research, appraisal analysis, and government policy initiatives.

8.1- Green Valuation: The role of Appraisal Methods

In Canada, the appraisal (or valuation) training methods are standard across the country and are developed by the Appraisal Institute of Canada (2010), through the University of British Columbia's School of Management. There are three major approaches to the valuation of real-estate, and they constitute the training as described by the appraisal manuals produced for

professionals in the field. These three methods are, the cost approach, the direct comparison approach, and the income approach (See Annex.2 for a description).

Globally, the integration of sustainability factors into the appraisal process was begun several years ago with the Vancouver Accord in 2007 (of which Canada is a signatory). The accord committed members of the appraisal community to the upholding of three major principles, they are:

- A review of how sustainability relates to the practice and standards of valuation.
- Working with stakeholders and supporters to promote awareness of and competency in the appropriate methods of addressing sustainability in valuations and appraisals.
- Working with those within and outside the valuation professional worldwide, to educate and inform about sustainability and its relationship to value.

In Canada, the integration of sustainability concerns into the appraisal process has begun and can be seen when one peruses the appraisal training literature for both the residential and commercial sectors. For the residential sector, sustainability education is included as an online development course for professional appraisers. The course workbook "Getting to Green: Energy Efficient and Sustainable Housing" (UBC, 2010) outlines information on what constitutes sustainability in the real-estate space and the issues around the definition of it, the benefits of green residential building, the specific technologies associated with green buildings and how to factor them into the appraisal process. With respect to sustainability, there are chapters which introduce the concepts of Life-Cycle Cost (LCC) and Life-Cycle analysis (LCA) in a general format (UBC, 2010, Pg. 2.10).

For the residential sector, the material described above constitutes the core of the education appraisers receive with respect to the appraisal of green features in the residential property sector. Throughout this manual, there are no simulation exercises which provide the appraiser with hands-on tools as to how to diagnose the value for green properties. For example, detailed guidance as to how to apply LCC/LCA, or suggestions as to how to gauge green demand is not discussed. Thus, this may provide one reason as to why we could not find a green premium when market-valuation was modelled residential properties. Essentially, we can perhaps argue that appraisers currently lack the tools necessary for valuing green features, even in markets where

they may possibly exist. Indeed, the review of Warren-Myers (2012) concluded that globally, there has been no consensus with respect to how the appraisal communities can effectively value green features.

For the commercial sector, sustainability is also a part of the appraiser's training as a professional development course offered online. The commercial 'green' training manuals are more detailed and provide appraisers with more hands-on training (UBC, 2010). It is argued that generally green building construction involves savings in terms of water and energy-use, better air-circulation, the use of recycled materials in construction, better waste management (the three r's: reduce, recycle, re-use). Other benefits could include being close to transportation amenities, more community gathering areas, etc (UBC, 2010, Pg. 1.18). The literature also provides the appraiser with a simulation exercise where a hypothetical building is being constructed with green energy-efficient (UBC, 2010).

Lastly, in the North American context, the Appraisal Institute of Canada (AIC) is responsible for developing the professional guidelines of appraisal practice used throughout the country (AIC, 2014). In addition to this material, the Appraisal Institute (U.S.-based) administers an educational program called the 'Valuation of Sustainable Buildings Professional Development Program' which provides comprehensive courses (online and classroom-based) on the green features of both commercial and residential buildings. In addition, the program also provides training on green valuation tools and case-studies. This program is accessible to both U.S. and Canadian-based appraisal professionals (Appraisal Institute, 2014), however, how much of this program has been accessed in either country is unknown, as it remains a voluntary component of the training of appraisers.

To sum up, the techniques for testing and incorporating the added effects of green features to the value of a home or commercial property are being included in the education provided to appraisers, albeit at an introductory/voluntary level. One may question whether these guidelines are being taken into account by the various appraisal agencies and individual appraisers as they conduct their work. Indeed, we can see (from the Annex.2) that the appraisal agencies practise a fairly standardised methodology with respect to the appraisal of properties. Most importantly, we observe from the websites of these agencies (BC Assessment/City of Calgary/MPAC/Ville de Montreal, 2014) that energy/water efficiency, healthier indoor climates (higher productivity), and

other green features do not receive added-attention, at least, it is not reported to be so. Therefore, considering the information at hand it is likely that these features and amenities are not awarded a premium in value calculation due to a lack of awareness and practical guidance.

Indeed, in an effort to survey whether appraisers and real-estate professionals around the world were engaged with sustainability Dixon et al. (2007) conducted a survey of 4600 professionals who were members of the Royal Institute of Chartered Surveyors (RICS). Their survey revealed that real-estate appraisers were, in general, followers when it came to engaging with sustainability issues and practices. When the results were broken into specific regions, the RICS membership from Canada did not fare well. The sustainability 'leaders' were members from Austral-Asia, Africa, the U.S., the U.K., and South America. The 'followers' were identified as Continental Europe, Canada, the mid-East, and South-East Asia (Dixon et al., 2007, Pg. 468). These results perhaps imply that perhaps our appraisal practices have not kept pace with international practices with respect to the incorporation of 'green' value..

8.2- Green Valuation: The role of the Policy Environment

Another reason as to why market-valuation figures have not been able to point towards a green premium could be that the policy structure at the local, provincial and/or federal level in Canada is limited or poses barriers against the realisation of higher demand for green buildings. We examined the policy structure at all levels of government to learn of the kinds of major supports being offered for green buildings in the country.

Our focus was to examine whether policy initiatives target green building demand. If we lack appropriate demand-side policy mechanisms, we can conclude that policy inertia is perhaps a contributing factor to the results achieved.

Table-8.1 below provides a review of the major federal, provincial/state, and local level programs currently in place in both countries[42]. This list was compiled from four major sources including the International Energy Agency (2007), the Commission for Environmental Cooperation (CEC), the Environmental Protection Agency (EPA) (EPA, 2014), and Natural Resources Canada (2014). We can see that both countries provide similar programmes and

[42] We have left out European initiatives since only one hedonic study in our literature-review originates from there. Plus, the policy environment and social environment in Europe may be significantly different than North American jurisdictions.

policies at all three levels of government. With respect to the U.S., given the size of the country, the number of cities, and a much higher population (approximately ten times Canada) there will ultimately be more public programmes and initiatives available. However, while we have shown that there are government programs targeting the development of green buildings in Canada, it is unclear as to what extent these programs are behind the growing demand for green certifications. For example, with respect to programs at the Federal level, the Canada Mortgage and Housing Company's Annual Report for 2013, highlights that the CMHC's loan insurance rebate program "continues to encourage the purchase of energy-efficient homes and/or energy-efficient renovations" (CMHC, 2013, Pg. 9). However, no figures are presented detailing how many individuals have accessed this program, or how many home purchases the program has aided.

With respect to the programs administered by Natural Resources Canada, their report to Parliament for the fiscal year 2011-2012 states that under the ecoEnergy Efficiency for Buildings programs, the 2011 National Energy Code for Buildings was published, a building energy simulation software was launched, building energy workshops were conducted, and over 1200 participants were trained. Similarly, under ecoEnergy-Efficiency for Housing program more than 800 building energy professionals were trained and more than 230,000 energy labels were issued (NRCan, 2013). However, what effect these programs entail in terms of raising market-demand for green features/certifications is unclear. With respect to provincial and/or local policies and programs, currently there does not exist much academic literature that has examined the effects of these policies upon green building demand growth. Therefore, one cannot make any firm conclusions at this time with respect to their effectiveness.

<table>
<tr><th colspan="6">Table 8.1 - Policy Comparison with United States - Green Buildings</th></tr>
<tr><th colspan="3">Canada</th><th colspan="3">United States</th></tr>
<tr><th>Federal</th><th>Provincial</th><th>Local</th><th>Federal</th><th>State-level</th><th>Local</th></tr>
<tr><td>Canada Mortgage and Housing Corporation
- Mortgage Loan Insurance Programme (I)</td><td>British Columbia
- Energy-Efficient Building Strategy (S)
- Efficiency Incentive Program (I)</td><td rowspan="2">Toronto
- Labelling (Toronto Green Development Standard) (L)
- Toronto Atmospheric Fund (I)</td><td rowspan="5">- Enterprise Green Communities (I & E)
- Federal Tax Credit (I)
- Energy-Efficient Mortgage (Fannie-Mae) (I)</td><td>California
- Emerging Renewables Rebate (I)
- Energy-Efficiency Financing Program (I)
- Home-Equity Financing (I)</td><td>Arlington, Virginia
- Green Building Tax Credit (I)</td></tr>
<tr><td rowspan="3">Natural Resources Canada
-ecoEnergy-Efficiency for Housing (L)
- ecoEnergy Retrofit for Homes (I)
-ecoEnergy-Efficiency for Buildings (E)</td><td>Ontario
- Net-Metering (I)
- New Home Construction (I)
- Mandatory disclosure (EA/L)
- Feed-in-Tariff (I)</td><td>Maryland
- Green building tax credit (I)</td><td>King County, Washington
- Green Building Incentives (I)</td></tr>
<tr><td rowspan="2">Quebec
- Techno-climat (I)
- eco-Performance (I)
- Heating with Green Power (I)
- Novo-climat 2.0 (I)
- Novo-climat (large buildings) (I)
- Reno-climat (I)
- Econologis (EA) (E)
- Eco-Renov (I)</td><td rowspan="2">Vancouver
- Rezoning, LEED silver (L)</td><td>Massachusetts
- Renewable Energy Trust (I)</td><td>Portland, Oregon
- Green Investment Fund (I)</td></tr>
<tr><td>New York
- Green Building Tax credit (I)</td><td>Seattle, Washington
- City Lights' Energy Smart Services (I)</td></tr>
<tr><td colspan="3" rowspan="4">I = Incentives (Tax-cuts, grants, loans, subsidies, etc.)
L = Labelling (certification - mandatory/voluntary)
E = Education (marketing/information/training/bench-marking)
EA = Energy-Audits
PB = Policy Bundling
S = Strategy (I/L/E/EA)</td><td>Connecticut
- Energy-Finance Investment Authority (I)</td><td>New York/Austin
- Energy-reporting from existing commercial building (EA)
- Mandatory audits (EA)</td></tr>
<tr><td></td><td>Austin/Berkley
- local certification (L)</td></tr>
<tr><td></td><td>Los Angeles/Boulder
- Property Assessed Clean Energy (I)</td></tr>
<tr><td></td><td>Santa Barbara/ Chicago
- Green Permit Program (PB)</td></tr>
</table>

Source: Commission for Environmental Cooperation (2013), Natural Resources Canada (2014), Environmental Protection Agency (2014), International Energy Agency (2007), Boehm (2010).

8.3 - Green Valuation: The role of Client Preferences

The role of the appraiser is not to create value, but rather to report it. Thus, the appraiser can only attach a green premium to the value of a property if the average consumer is known to value these features in that market (AIC, 2010). Given that our study has not been able to establish a case for the existence of a green premium for market-valuation (or prices), we should therefore ask the question as to whether the real-estate clientele (customers) in Canada place a premium on green features. That is, do our findings concur with market sentiment in the country? If consumer sentiment is agnostic with respect to green features or certification, then our findings are reflective of market sentiments.

We have been able to locate only one academic study focused upon this question for the Canadian real-estate market. The study entitled, "Willingness to pay and preferences for healthy home attributes in Canada" by Spectic et al. (2005), investigates the socio-economic factors which increase the odds of a home-owner paying for healthier home attributes in the Canadian context. Respondents were asked if they would be willing to pay extra if they were guaranteed that their new home purchase would have better indoor air quality, lighting systems, and acoustics. Their findings indicate that knowledge about 'healthy' home attributes is positively related to the willingness to pay for them. Furthermore, those who were in the higher income brackets and with an active lifestyle, were also more willing to invest in healthy home attributes. (Spetic et al. ,2005). Therefore, going back almost a decade, we can see that there is some limited evidence of preferences for green or 'healthy' home features amongst some members (both home-owners and renters) of the residential real-estate clientele[43]. However, we must keep in mind that expressing the willingness-to-pay when faced with hypothetical scenarios will not necessarily lead to actual purchases and behavioral change.

Outside of the academic realm, over the past several years a number of surveys have been conducted to evaluate how real-estate clientele view green building features and technologies (See Annex.7).

These studies, on the whole, indicate that a portion of home-owners and buyers are interested in green features, and that they are willing to take some minimal and meaningful steps to achieve greater resource efficiency for their homes. However, how important these features and technologies are when measured against other home features, requires more research. We must also be mindful that these are hypothetical scenarios.

Furthermore, given that these studies are not (for the most part) publicly available (online) it is hard to evaluate the questions asked and the level of methodological rigor applied. These studies do not originate from academic sources and have not been published in peer-reviewed journals. However, if these sentiments do reflect the market, it is likely that they would not have been

[43] NOTE: Using our residential and commercial samples, we modelled the probability of a building being certified using logistic regression (See Annex.6). In our case, neither the residential nor the commercial models were significant. The residential model showed that the odds of a building being certified go up if it is located within the city (not in the suburbs) and is bigger. However, neither variable was significant. Similarly, the commercial model demonstrated that the odds of being certified go up if the building is a Class A building and is bigger, however, the variables were not significant.

captured by our model given that the appraisal profession still has not developed a consensus on how to value green.

8.4- Green Valuation: The role of Methodology and Study Limitations

Lastly, it is also important to examine the methods we have utilised to test the certification variable and the possible limitations associated with them. Essentially, we need to investigate whether there are flaws in our modelling techniques which may have biased the results.

Methodology and study limitations: The role of sample-size

As is evident from the literature review section, the vast majority of hedonic studies have utilised much larger samples of both residential and commercial properties to model their hedonic equations. Our sample size consisted of 130 residential properties and 191 commercial properties. Furthermore, the sample for the residential model was restricted to two provinces due to data availability. Thus, on the residential side, one may argue that the study is at best perhaps only indicative of a narrow set of markets in two provinces and the wider 'national' picture with respect to valuations could be different. The vast majority of the commercial hedonic studies that have been described were estimated using samples well beyond a thousand, with the exception of Dermisi's (2009) study of market and assessed-values. However, whether a larger sample would have yielded different conclusions is contentious given the issues with appraisal mentioned earlier.

Methodology and study limitations: The role of modelling techniques

In terms of methodology or regression techniques used, the majority of reviewed hedonic studies relied upon linear models using the OLS technique. We utilised the same methods for our regression models. However, Dermisi (2009) and Wiley et al. (2010) did employ techniques which require mention. While Dermisi utilised OLS as one of her regression methods, she also used a spatial lag regression model in her analysis to control for the effects of spatial dependence. Often observations are related to each other when they occupy spaces in close proximity. For instance, the sale price of a property on the next street over may influence the sale price of a 'subject' property. In that case, the influence of the explanatory variables cannot be reliably estimated for the subject property. The OLS technique ignores these relationships, while the spatial lag regression modelling approach factors this dependence into the regression analysis

(Wimpy, 2014, Pg. 2-3). While this technique may be necessary for most real-estate analyses, it is unlikely that it is needed in our case since our sample is made up of properties which are not situated in a 'contained' space but are rather spread out across unconnected regions and neighborhoods (especially in the case of the residential data). Furthermore, the incorporation of this technique would likely not change our conclusions with respect to the certification variable. Lastly, this was also the only study to incorporate this technique.

The study by Wiley et al (2010) incorporates the two-stage least squares modelling technique in addition to OLS. According to regression theory, in some instances the explanatory variable tends to be correlated with the error term (what is not included in the model). If this correlation cannot be removed, the OLS technique cannot be relied upon to yield reliable regression co-efficients. The two-stage least squares technique is used correct for this issue. It involves the use of an 'instrumental variable' that is correlated with the dependent variable, but is not correlated with the error term. However, finding a reliable instrumental variable that performs this function is difficult. There is no unique choice of an instrument, since many variables could be uncorrelated with the errors and correlated with the dependent variable (Wooldridge, 2012, Pg. 528-529). Given the potential for errors associated with this technique, this avenue was not pursued by us. More importantly, it is unlikely that this technique would alter our general results with respect to certification. Also, when the errors of both our residential and commercial models were correlated (Pearson) with the continuous dependent variables (Residential - age and floor area, Commercial - square-root of age, log-floor area), no statistically-significant correlations were found.

Lastly, in terms of model-specification, the dependent variables in almost all cases were the logarithms of sale and/or rental prices, once again, not different from ours (log-evaluation). The number of explanatory variables used in our model were lesser in number as compared to the hedonic models utilised by the authors of the other hedonic models. However, we achieved a high r-square (almost 90%) for the residential model using robust-regression, and over 80% for the commercial model. This level of explanatory power is higher than the majority of hedonic models tested by the other authors (see Literature-Review). It must re-asserted as well that the objective of our analysis was not to build the most complete regression model, rather, it was to allow the certification variable the greatest chance to 'show' itself statistically. In both sets of

models, standard diagnostic tests were performed (linear correlations, checks for linearity, etc.) to examine and assess the variables.

Furthermore, in order to complement the OLS models, logistic regression models were also utilised to cross-check the results. These exercises led to the same conclusion. However, we must concede that it is possible that a green premium could be found with the use of selling-price as the dependent variable.

Therefore, we may conclude that overall there does not exist great differences between the modelling techniques utilised by us and the established literature in this field. Perhaps, the most significant difference between our study and the wider literature is not in the methodology or regression techniques applied, but rather the dependent variable. It is conceivable that if the willingness-to-pay studies and surveys we reviewed are correct, then the use of selling-price as the dependent variable would have yielded different results.

Summary

To sum up, we have examined four plausible explanations for why our hedonic model results do not show a green premium. With respect to the appraisal sciences and practice, we examined the current state of education in Canada, and there is some reason to believe that perhaps the appraisal community (in Canada, and perhaps abroad) are still unable or unwilling to integrate fully sustainability into their practices, contributing to our 'negative' results (although, lack of market demand could be a factor as well).

We also examined our green building policy structure in Canada at different levels of government and found that we have, like the U.S., started to promote green building development through a combination of both financial (and non-financial) incentives. However, how effective these policies are and whether they also serve as obstacles to green building demand requires greater analysis. Thirdly, when we reviewed some of the public surveys which have been conducted in Canada, the results have shown that there may be support amongst some parts of the real-estate clientele for green features. However, these studies have not been undertaken by the academic community, and their relevance and the weight of the evidence is unclear. Indeed, if this evidence was as strong as claimed, then there would be little reason for the appraisal community to be cautious. Lastly, we reviewed the methods used by us, and

concluded that our regression models resemble to a large extent the other hedonic regression models used in this genre of study. However, our sample-size is restricting and may not be representative of the national valuation scenario. Most importantly, we must bear in mind that in our case the dependent variable was market-valuation, whereas most hedonic studies have used selling-price. Based on our discussion thus far, we will now proceed to discuss some recommendations for academia, industry, the appraisal and communities.

9 - Recommendations

In our introductory chapter, we introduced the idea of the circle of virtue (Fig-1.10). This is a real-estate industry that is 'pro-green'. In such an industry, the occupiers, builders, developers, and investors all support in tandem the development and purchase of green buildings. We also stated that progress towards the circle of virtue will require in part 'positive' socio-economic evidence that in turn will encourage greater levels of green building development. Our study has not been able to provide significant evidence of such progress (albeit with limited data). However, as stated earlier, a 'negative' result can also point towards actions that key stakeholders in the real-estate space can undertake. As such, we will now proceed to provide recommendations that industry, academia, appraisers, and government can undertake in the years ahead so that future analyses of this type are able to find more concrete evidence of the green premium, thereby helping us to transition towards the circle of virtue.

Academia/Industry

As we saw in our literature-review, the vast majority of the literature focussing upon the question of the green premium has been carried out in markets and jurisdictions outside of Canada. From an appraisal/investment underwriting perspective there is a need to strengthen the amount and sophistication of socio-economic research conducted in Canada with respect to green buildings.

First, from a resource-perspective, we need to create publicly-available and comprehensive data-bases which allow researchers to identify, track, and model the economic performance of green buildings (particularly the selling prices of properties). Future studies must incorporate larger data-sets which are more reflective of the real-estate market of Canada. As such, the next generation of studies should examine other markets across the country, and the green demand dynamics in sub-markets, as valuation is performed using information at the neighborhood and city-level.

Secondly, the research themes and methods should be broadened to include qualitative approaches. Hedonic models serve to demonstrate average relationships, however, we must also be able to investigate the 'exceptions', intricacies, and contradictions in each market with respect to consumer behaviour, tastes, and spending habits. While most studies seem to utilise the

certification variable as signifying green features, more research needs to be performed examining which features are actually valued and capture investment from the perspective of the consumer. Qualitative research methods can help in this regard, creating a more complete profile of both the market and the consumer. The study of Spetic et al. (2005) was a beginning, now is an opportune time to carry the investigation further. Given that consumer surveys, at times, tend to originate from interested parties or key stakeholders, there is a need for more objective sources and methods to undertake these types of analyses.

Thirdly, some of our results point to the need to look at metrics beyond market-value assessment, particularly prices and vacancy-rates. In our study, we found 'limited' evidence that a green premium may exist in terms of selling prices (see Paired-Analysis results). Also, the vacancy-rates of green commercial buildings were lower (although not statistically significant). It is quite possible that hedonic modelling incorporating those variables (with a larger sample) would have yielded different results. Thus, we should replicate the kinds of hedonic analysis presented in the literature-review in the context of Canada. An interesting exercise would be to use price as a the dependent variable and compare the results to when market-valuation is used as the dependent variable. Similarly, with larger samples, even small differences in means are statistically-significant. Therefore, vacancy-rate analysis with a bigger sample could lend support for a green premium.

There is also a need to conduct more policy-based research, specifically comparing the effectiveness of different policy options with respect to the promotion of green building market-demand and transformation[44]. Green building policies are in force across the country; however, what kinds of policies are most effective in which contexts requires further research. This kind of literature is currently missing from the academic community. Most of the policy literature has been authored by international organisations such as the International Energy Agency, the Commission for Environmental Cooperation, and the individual agencies of the United Nations. While these analyses are useful for comparing policies across countries, they tend to be overarching and 'general'. As such, the application of the recommendations may not necessarily apply in all (or Canadian) contexts.

[44] These efforts may help bring about strong evidence of the green premium through positive effects upon market-transformation.

Appraisal Community

We have discussed that although the valuation of green properties has been addressed to some degree in the training materials provided to appraisers, it is unclear as to what extent the valuation agencies use some of those ideas and techniques.

Based on a review of the European Immo-value (2014) project and the writings of Lorenz and Lutzkendorf (2011), and Warren-Myers (2012), the basic conclusion we can make with respect to the 'new' approaches to green valuation is that the new proposed techniques require only a modification of the three existing valuation approaches. Most of the 'new' literature stresses the use of the income approach to value for the incorporation of sustainability. Generally, it is argued that sustainability affects costs (both upfront and operating), revenues (sales), and risks (discount rates), it is through these metrics that sustainability can be integrated into the valuation process. However, more work needs to be undertaken on defining and agreeing on how to alter current direct-comparison and cost approaches. Furthermore, a common weakness among these proposals is the fact that simulation exercises incorporating a range of valuation scenarios are either non-existent or weakly developed, or the techniques are of no relevance to the appraisal profession (Warren-Myers, 2012). In our opinion, as a first step, producing a greater number of academic-level studies focussing upon the mapping of the real-estate space in Canada with respect to consumer preferences is a good first step. Any incorporation of green value into valuation and under-writing (as suggested above) must be based on market-evidence and that is what must be constructed first.

Public Authorities

As with all green technologies, policy action or inertia can impose a big effect. The right mix of policies can help aid the transition towards the circle of 'virtue' mentioned earlier. A study of the most recent policy literature internationally reveals practices and ideas which our governments should research, assess and consider going forward. We have examined some of the major policy publications produced by the International Energy Agency[45], as well as other literature authored

[45] See Energy-Efficiency in the North American Existing Building Stock (2009), Financing Energy-Efficient homes (2007), Modernising Building Energy Codes (2013), Transition to Sustainable Buildings: Strategies and Opportunities to 2050 (2013), Energy performance certification of buildings: A policy tool to improve energy-efficiency (2010).

from the North American perspective[46]. The policy initiatives described below were chosen on the basis of the number of mentions they received in our review, and perhaps represent some of the latest (attainable) policy thinking and practice with respect to green buildings. This is not meant to be an exhaustive list, but represent a small collection of initiatives that are growing globally. As is often the case with new technologies, public-policy can be an aid or a hindrance. With the right mix of prudent supports, green building can better weather some of the risks and uncertainties that plague their development. Specifically, these policy prescriptions can help boost demand for these homes by lowering investment risk and shedding light on the benefits they can offer.

Financing

Cost (both for purchasers and builders) is one of the key barriers acting against green building demand and investment (McGraw-Hill Construction, 2013). A 2013 study published by the Commission for Environmental Co-operation identified financing mechanisms which could help stimulate the demand for green buildings by easing some of the financial risks associated with them. Their study was based upon literature reviews and interviews with green building experts across North America. This report identified three financing mechanisms which are growing across the continent, have exhibited some success, and could encourage greater the purchasing of and investment in green buildings in the Canadian context. These mechanisms are, pay-as-you-save (PAYS), Property Assessed Clean Energy financing, and Green Mortgages. These models are described below:

- **Pay-as-you-save:** This is a mechanism whereby loans are provided to building owners and investors to pay for purchases of and/or upgrades to new and existing buildings. In this case, the funding source is government or utilities. The investor may pay off the bill directly or through their utility bills[47]. This financing mechanism seeks to address the problem of high capital costs which green buildings are often reputed to entail.
- **Property Assessed Clean Energy:** In this model, private capital is mobilised to provide for the financing of green retrofits in commercial buildings. The property is used as

[46] See Boehm (2010), Issa et al. (2010), Commission for Environmental Cooperation (2013).
[47] If the loan is tied to the investor, then he/she must have a long-term horizon in order for the mechanism to be financially worthwhile. Otherwise, the benefits may accrue to the subsequent owner(s).

collateral thereby providing security to investors. The green bonds issued by public authorities are sold by building owners to pay for needed green retrofits. The loan repayments are made through property tax bills over time.

- **Green Mortgages:** These mortgages involve supplying financing to home-owners for the purchasing of green properties. Essentially, traditional mortgages are altered slightly to suit the needs of green home purchasers. Some of these features include; mortgages with interest rate buy-downs, mortgage refinancing, subsidized mortgage insurance, mortgage loan insurance provision (by public authorities), and longer amortisation periods.

Information

As green buildings are a growing technology, there is still uncertainty as to the kinds of benefits these building provide, even amongst green building professionals themselves. This is a barrier to green building investment at both the domestic (Issa et al., 2010) and international levels (Dixon et al., 2008). Hence, policy programs that are designed to stimulate market-demand for green buildings need to incorporate solutions which are intentioned to address some of the information gaps and biases which continue to persist globally. Some of the latest policy prescriptions that can help address the lack of awareness include:

- **Certification and Labelling**: Domestically, the responsibility for building regulation lies with the provinces and territories, therefore code regulations can impose minimum standards or certification for at least new construction, such as in the case of Ontario and Toronto (CEC, 2013). Labelling has the benefit of informing a potential customer as to the potential savings he/she could receive from making a green purchase. As such, it performs a powerful informational and bench-marking role. Ignorance of the benefits of green properties continues to plague the industry (Issa et al., 2010)
- **Time of sale disclosure and home energy-audits prior to sale**: Ontario has also in the past mandated that homes undergo energy audits prior to their sale (Boehm, 2010)[48]. These kinds of mechanisms could be particularly effective in helping to spur green demand if both environmental awareness and energy prices climb in the future. It may enable prospective buyers to purchase homes based in part on environmental criteria and

[48] These measures have also been implemented in New York and Austin (CEC, 2013).

information. Currently, environmental information is generally missing from the discussion when it comes to (particularly) residential purchasing decision, as a couple of the consumer surveys we described have stated.

- **Smart-Metering**: The use of Smart-metering is an effective tool for providing both the utility and the consumer information as to the impact that their energy-use has upon energy consumption and their household utility costs. These programs have been launched in some provinces (Ontario and British Columbia), and could be considered in other jurisdictions as well. If consumers are better educated and informed with respect to their energy footprint, then they are more likely to pursue purchases of green building, or renovate existing buildings up to a green standard.

10 - Concluding Remarks

In order to investigate the question of whether green buildings capture higher market-valuations and prices, we undertook various statistical analyses examining metrics such as market-valuation, prices, and vacancy-rates. With respect to the principal analysis, our hedonic models did not yield conclusive evidence of a green premium (vis-a-vis market-valuation), as almost all the certification variables were not significant. However, we have also discussed that these results could be due to the fact that the appraisal industry is likely not attaching premiums to green properties when they are valued given that appraisal techniques are still in the process of being refined. While efforts are currently underway to develop a new generation of valuation techniques, they can only be applied if market-evidence points to the existence of a green premium. As such, we must also strengthen both the amount and sophistication of socio-economic research concerning green building in Canada. Both academic and industry researchers have a key role to play in this effort.

Secondly, our analysis of commercial vacancy-rates in Calgary, Toronto, and Montreal showed the strongest evidence of a green premium as, on the whole, green buildings did show lower vacancy-rates, however, the differences were not statistically-significant. Lastly, when we undertook a paired-analysis of three residential properties we failed to observe a price premium for all the properties. However, given that a price-differential was noticed in most cases, the result points to the fact that perhaps economic-modelling using price as the dependent variable would have yielded more positive results. As such, one of the priorities of the academic/industry communities should be to continue more advanced economic modelling incorporating a wider range of variables and methods to shed light on the clientele and the economic dynamics at play behind the growth of certifications and green demand.

While this study did not lead to evidence of a green premium in the limited contexts of the few markets and metrics studied, we consider this analysis as a beginning and it has pointed to some key areas and actions different stakeholders can focus upon and take in the years to come with respect to research, policy, and valuation practice. Economic research related to green building growth and performance is nascent, and much more work needs to be done in the future to

strengthen both the performance of certified green buildings and solidify the argument as to why we should pursue them

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Annex 1 - Regression Outlier Descriptions

Property	City	Age	Floor Area	Bed	Bath	valuepersqft
1	West Van	10	4009	5	6	1060.54
2	White rock	54	2736	2	2	658.77
3	Vancouver	5	2414	4	4	979.88
4	Vancouver	8	2798	5	5	834.60
5	White rock	45	1263	3	1	691.68
6	White rock	30	2834	2	3	582.19

Property 1

This detached property is located in the suburb of West Vancouver at the edge of the mountain-ranges surrounding the city of Vancouver. It is described as having elevated ocean-views, and is situated 4 kilometers from the Pacific coast. The mountainous location combined with views of the ocean, and a larger house-size area the factors which mostly likely entail a higher market-valuation for this property.

Property 2

This detached property is located in the suburb of White-Rock, just south of the city of Vancouver. While it is a an older property, it is located approximately 600 meters from the coast, which is the most probable reason for the higher market-value of this property.

Property 3

This detached property is centrally located in the city of Vancouver (the Arbutus Ridge), less than a hundred meters from the Spirit Regional Park, and approximately 3 kilometers from the beach and the University of British Columbia. These conveniences combined with the fact that it is a relatively new property most likely account for the higher valuation of this property.

Property 4

This detached property is located in the same location and street as 'outlier' property number 3 (in the Arbutus Ridge area). Given the amenities nearby (University of British Columbia, Spirit Regional Park, and proximity to the coast), the higher market-valuation of this property is understandable.

Property 5

This detached property is located in the suburb of White Rock, adjacent to the City of Vancouver. While it is an older property and is of modest size (1263 sq.ft), it is located only 400 meters from the Pacific coast and these factors most likely account for the higher valuation.

Property 6

This detached property is located in the suburb of White Rock, adjacent to the City of Vancouver. Like some of the other outlier properties, it is slightly older (30 years, as of 2013). It is also located approximately 600 meters from the Pacific coast. As such, it has achieved higher market-valuations.

To sum up, the residential outliers all come from the Greater Vancouver region, the higher valuations these properties have achieved is due largely to the fact that they are centrally located and/or are in close proximity to the coast (or in one case, have ocean views). The relatively higher valuations of these properties are confirmed by the fact that the average value per-square foot of properties in the Vancouver area (from our sample) is $407.83. All the properties listed above far exceed this figure. Lastly, it should be noted that none of these properties have received certification.

Commercial Outliers

Property	Floors	typical	age	sq. Ft	Shop	food	Fitness	valuationadj	valuepersqft
1	17	15600	34	241457	0	0	0	8759840	36.279089
2	3	9000	102	17077	1	0	0	30270093	1772.565
3	12	30000	59	334589	0	0	0	955400000	2855.4435

Property 1

The first property is located in downtown Calgary. It is very centrally located in the core of the business district on 5th avenue south-west. However, it is a slightly older property (34 years as of 2013) with no shopping, food, or fitness facilities. Furthermore, its value per-square foot is low ($36.28). Therefore, unlike most of the outlier properties for both the residential and commercial sectors it has a relatively low evaluation despite being classified as a Class A property.

Property 2

The second commercial outlier property is located in the downtown core of Toronto on Yonge Street. Although it is only a 3-storey building (and a Class C property), it receives a high value per square foot ($1772.56) due to its central location in one of the key business districts in Canada. It is adjacent to key landmarks in the city such as the Provincial Legislature, Dundas Square, Bay Street, University of Toronto, and Ryerson University. It is serviced by public transit, both subway and streetcars.

Property 3

The third commercial outlier property is a class B located in the downtown core of Montreal on one of the main business arteries (de Maisonneuve boulevard). While it is an older property (59

years old as of 2013) and has no shopping, food, or fitness facilities, it is conveniently located and adjacent to McGill University and University du Quebec a Montreal in the Latin quarter. Given these conveniences, it receives a relatively higher valuation ($2855/sq.ft).

To sum up, the outlier properties 2 and 3 are properties which have relatively high valuations, most likely due to their central locations and proximity to key city amenities. In the case of property 1, despite its central location, it receives a relatively low valuation, perhaps due to poor maintenance/quality issues. Lastly, it should be noted that none of these properties were certified at the time of study.

Annex 2 - Appraisal Methods

Given that we have mentioned the three major valuation methods used by appraisal agencies, it is appropriate to provide a general description of their methods for descriptive purposes. They are:

- **Direct Comparison Approach**: According to the standard Canadian manual on appraisal techniques, "The appraisal of Real-Estate", the direct comparison approach to valuation entails developing an estimate of value by comparing the subject property to similar properties that have recently sold in the same neighborhood. The factors which may be taken into account may be physical (age, size, lot-size, number of bedrooms, etc.) or financial (property rights, financing terms, etc.). These variables are used to find the appropriate comparables, make adjustments, and create a value for the subject property (Appraisal Institute of Canada, 2010, Pg. 13.1-13.2).
- **Income Approach:** Given that income-producing real-estate is purchased as an investment, the earning power of the property is what gives it value. Hence, in this approach, the appraiser analyses a property's capacity to generate future income, and capitalises this income to indicate the present value of the property. The steps involve estimating gross income from all sources, deducting an allowance for vacancy and bad debts, and further deducting direct and indirect operating expenses. The resulting net-operating-income is then divided by the capitalisation rate to obtain market-value (Appraisal Institute of Canada, 2010, Pg. 20.1-20.2).
- **Cost Approach:** This approach also relies upon market comparisons to establish a value for a property. In this approach the value of the property is established by examining the cost of a new or substitute properties with the same utility as that of the subject property. Once this cost estimate has been found, it is adjusted for depreciation that is evident in the subject property (Appraisal Institute of Canada, 2010, Pg. 17.1-17.2).

The three approaches to valuation described above are techniques that are followed globally by appraisers to calculate the value of real-estate. These techniques have also been used the appraisal agencies cited by us. Below is a description of the appraisal methods used by these agencies.

British Columbia: Appraisal Structure and Methods

BC Assessment is the crown corporation that is entrusted with establishing the market value of real-estate in the province of British Columbia. According to official policy, the agency takes into account the location, size, topography, shape, replacement cost, age, condition, rental income and the sales of comparable properties in the area to determine the particular value for a property. These metrics are utilised with the three major approaches to value-calculation. The approaches used to value property in the province are the Direct Comparison, Cost, and Income methods. In some instances, the agency may perform an actual inspection of a property to analyse its features within (BC Assessment, 2014).

Calgary: Appraisal Structure and Methods

In the case of Calgary, the assessment is performed by a local agency as opposed to a provincial body (as in the case of British Columbia and Ontario). Office buildings in the city are assessed using the income approach. In order to establish value for a property, the appraiser evaluates factors such as property size, quality, age, location, and class. Mass appraisal (at the neighborhood level) may also be employed to assess the value of a property. However, mass appraisal may miss out on the finer details/features of green buildings (City of Calgary, 2014).

Ontario: Appraisal Structure and Methods

Property assessment in Ontario is performed by the Municipal Property Assessment Corporation (MPAC). For office properties, the income and cost approaches to valuation are utilised, whereas for residential properties all three approaches (Direct Comparison, Income, and Cost) may be used. Their policy is to inspect all office buildings to obtain physical information relating to size, storeys, class, quality, services, parking, and storage, etc. In addition, information is also obtained with respect to financial metrics such as sales, rents, operating expenses, etc (MPAC, 2014).

Montreal: Appraisal Structure and Methods

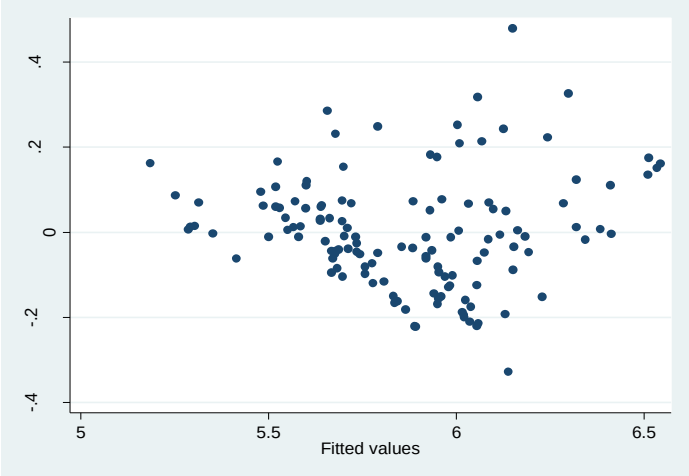
In Montreal, the valuation exercise is also undertaken locally by the city. Their approach to valuation comprises the direct comparison, the cost, and income approaches (in line with other valuation agencies).

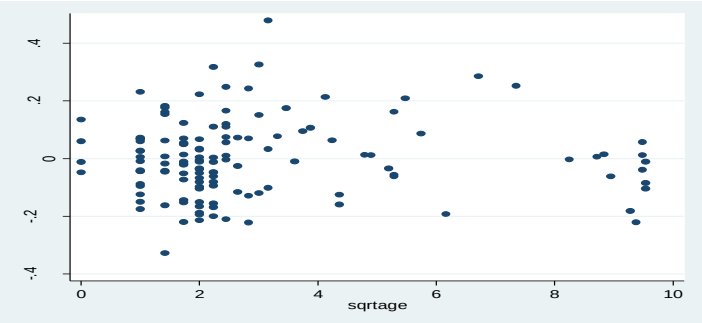
Annex 3 - Results of Residential Log-Evaluation model (with Square-root of Age, Log Floor Area)

Linear regression		Number of obs = 131 **F(10, 120) = 79.32** **Prob > F = 0.0000** **R-squared = 0.8242** Root MSE = .13832	
	Robust		
logevaluation Coef.	Std. Err.	t	P>t
_Ictytype_2 .0776469	0.042669	1.82	0.071
_Ictytype_3 .0611145	0.04217	1.45	0.15
_Ictytype_4 .3100409	0.045061	6.88	0
sqrtage .0056839	0.006458	0.88	0.381
_Ipropertyt_2 .0834144	0.067621	1.23	0.22
_Ipropertyt_3 .1233655	0.059684	2.07	0.041
logfloorarea 1.023373	0.109023	9.39	0
certification -.0226393	**0.023874**	**-0.95**	**0.345**
basement .1107076	0.029156	3.8	0
residential .1371357	0.038486	3.56	0.001
_cons 2.010666	0.330822	6.08	0

Test for Error Normality						
Variable		Obs	W	V	z	Prob>z
	e	131	0.98007	2.066	1.633	0.05122

Test for Multi-Collinearity		
Variable VIF	1/VIF	
_Ictytype_4	3.89	0.256996
_Iproperty~3	3.11	0.321929
logfloorarea	2.62	0.381185
_Ictytype_3	2.56	0.390532
_Ictytype_2	2.45	0.407613
residential	1.96	0.509341
_Iproperty~2	1.91	0.523331
sqrtage	1.76	0.569037
basement	1.52	0.659128
certificat~n	1.17	0.853218
Mean VIF	2.3	

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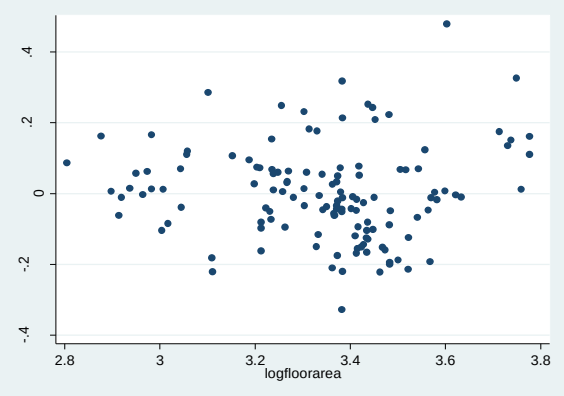
-.2
-.4
0
2
4
6
8
10
sqrtage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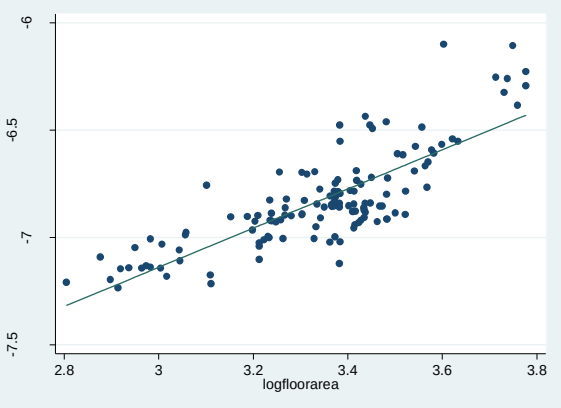
3
3.2
3.4
3.6
3.8
logfloorarea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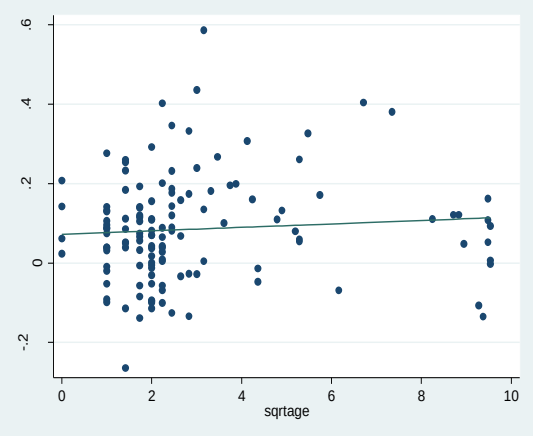
logfloorarea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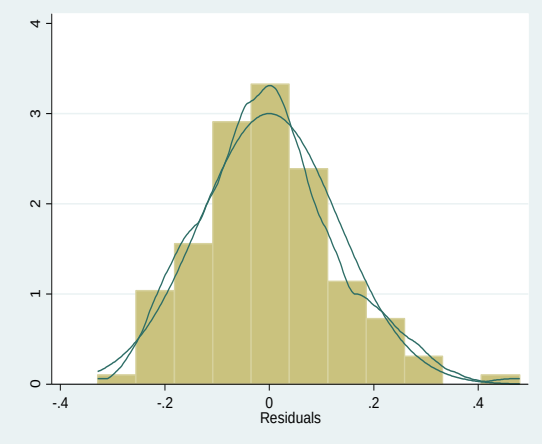
6
8
10
sqrtage


4
3
2
1
0
-.4
-.2
0
.2
.4
Residuals

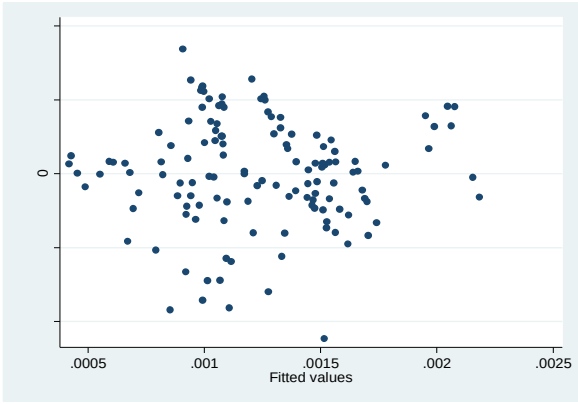
Annex 4 - Results of Residential Inverse Square-root model (with Square-root of Age, Log Floor Area)

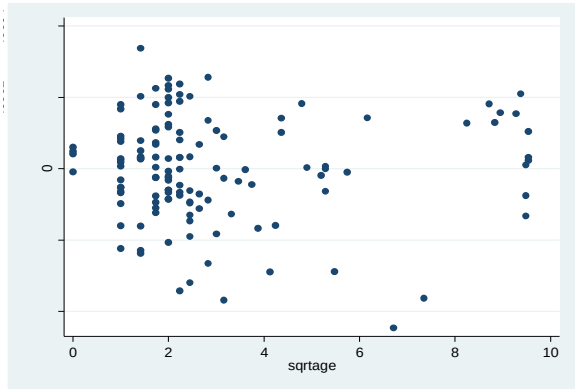
Linear regression		Number of obs = 131 F(10, 120) = 149.20 Prob > F = 0.0000 Root MSE = .00015 R-squared = 0.869 Root MSE = .00015	
	Robust		
Inverse-Square Root Coef.	Std. Err.	t	P>t
_Ictytype_2 -4.17e-06	4.79E-05	-0.09	0.931
_Ictytype_3 -.0001034	4.93E-05	-2.1	0.038
_Ictytype_4 -.0004077	5.15E-05	-7.92	0
sqrtage .0000116	7.45E-06	1.55	0.123
_Ipropertyt_2 -.0001748	6.98E-05	-2.5	0.014
_Ipropertyt_3 -.0001266	6.88E-05	-1.84	0.068
logfloorarea -.0012402	0.000107	-11.62	0
certification .0000313	**2.66E-05**	**1.18**	**0.242**
basement -.0001081	3.21E-05	-3.37	0.001
residential -.0001231	4.19E-05	-2.94	0.004
_cons .0058197	0.000327	17.8	0

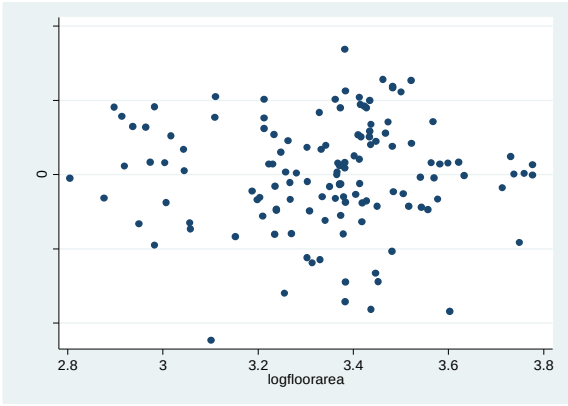
Test for Error Normality						
Variable		Obs	W	V	z	Prob>z
e		131	0.98196	1.87	1.409	0.0794

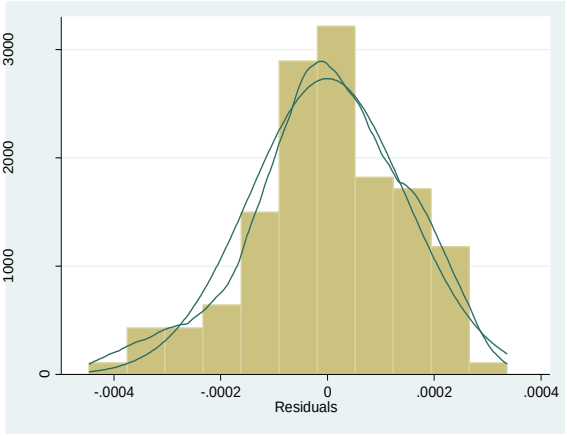
Test for Multi-Collinearity		
Variable	VIF	1/VIF
_Ictytype_4	3.89	0.256996
_Iproperty~3	3.11	0.321929
logfloorarea	2.62	0.381185
_Ictytype_3	2.56	0.390532
_Ictytype_2	2.45	0.407613
residential	1.96	0.509341
_Iproperty~2	1.91	0.523331
sqrtage	1.76	0.569037

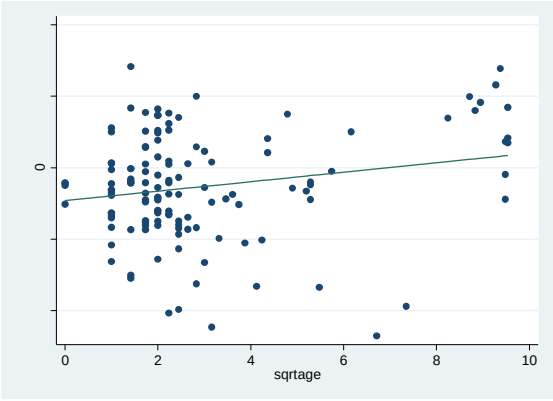
basement	1.52	0.659128
certificat~n	1.17	0.853218
Mean VIF	2.3	

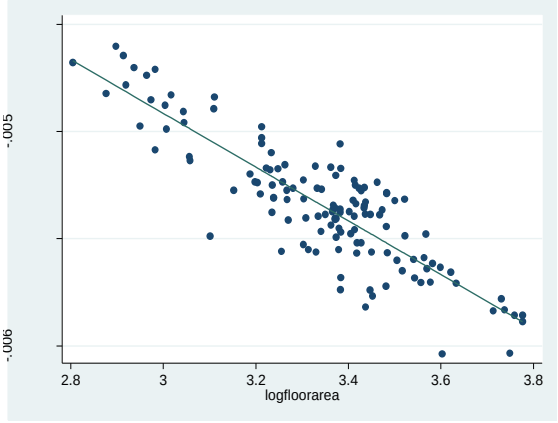












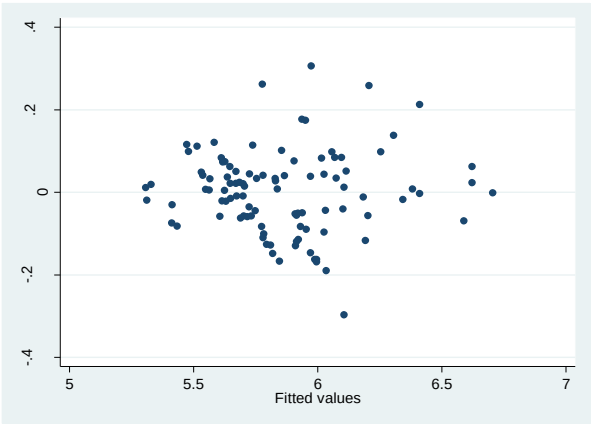
Annex 5: Residential Hedonic Model 2: Higher proportion of Green buildings

Linear Regression				**Number of observation**		**101**
				F(10, 90)		**139.34**
				Prob > F		**0**
				R-squared		**0.894**
				Root MSE		**0.10585**
		Robust				
logevaluation	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% Conf.**	**Interval]**
_Ictytype_2	0.0575	0.0380	1.5100	0.1340	-0.0180	0.1329
_Ictytype_3	0.0445	0.0383	1.1600	0.2490	-0.0316	0.1207
_Ictytype_4	0.2950	0.0439	6.7100	0.0000	0.2077	0.3824
age	-0.0016	0.0005	-3.4800	0.0010	-0.0025	-0.0007
_Ipropertyt_2	0.1277	0.0548	2.3300	0.0220	0.0189	0.2365
_Ipropertyt_3	0.1293	0.0559	2.3100	0.0230	0.0183	0.2403
floorarea	0.0002	0.0000	11.1200	0.0000	0.0001	0.0002
certification	-0.0138	0.0211	-0.6500	0.5150	-0.0557	0.0281
basement	0.1241	0.0277	4.4800	0.0000	0.0690	0.1792
residential	0.1104	0.0360	3.0700	0.0030	0.0389	0.1819
_cons	5.0605	0.0724	69.9400	0.0000	4.9167	5.2042

Test for Error Normality					
	Shapiro-Wilk Test for Normal Data				
Variable	Obs	W	V	z	Prob>z
e	101	0.98262	1.447	0.820	0.20607

Test for Multi-Collinearity		
Variable	VIF	1/VIF
_Ictytype_4	3.61	0.27697
_Iproperty~3	2.8	0.35758
_Ictytype_3	2.46	0.40582
_Ictytype_2	2.27	0.43969
residential	1.94	0.51485
floorarea	1.94	0.51556
_Iproperty~2	1.91	0.52478
basement	1.64	0.60844
age	1.56	0.64189
certificat~n	1.11	0.89902

Mean VIF	2.12	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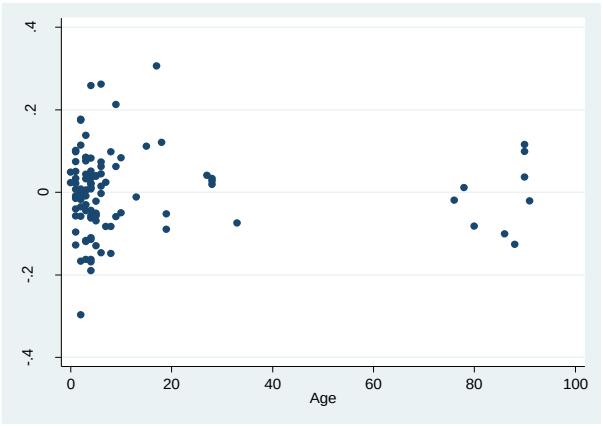
-.2
-.4
5
5.5
6
6.5
7
Fitted values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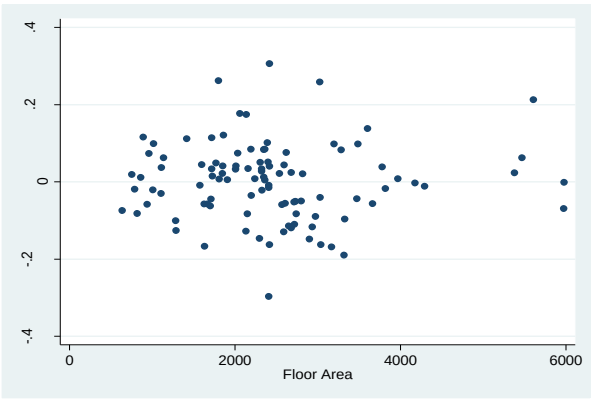
0
20
40
60
80
100
Age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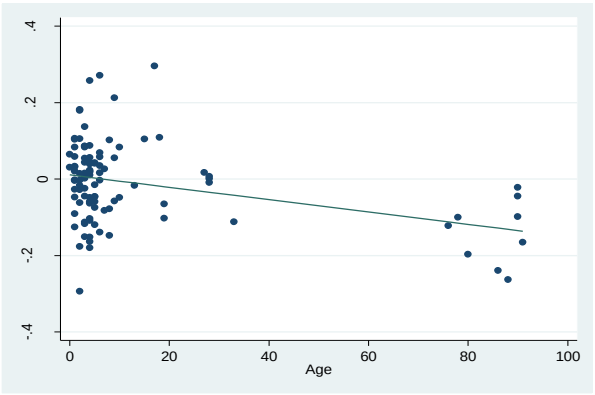
-.4
0
2000
4000
6000
Floor Area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0
20
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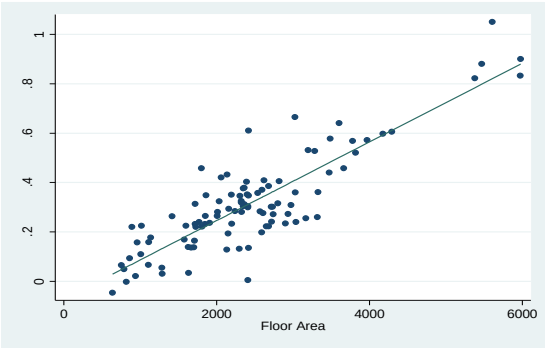
60
80
100
Age


1
.8
.6
.4
.2
0
0
2000
4000
6000
Floor Area

Annex 6 - Logistic Model : Determinants of Certification (Residential and Commercial)

Residential Logistic Model

Logistic regression					Number of obs	131
					LR chi2(7)	2.93
					Prob > chi2	0.8914
Log likelihood = -75.560973					Pseudo R2	0.019
certification	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
smallcity	0.8911	0.8335	-0.1200	0.9020	0.1425	5.5729
medcity	0.8747	0.7149	-0.1600	0.8700	0.1763	4.3409
largecity	0.9290	0.6914	-0.1000	0.9210	0.2161	3.9948
residential	1.3619	0.6867	0.6100	0.5400	0.5069	3.6591
detached	0.9563	0.7323	-0.0600	0.9530	0.2132	4.2899
age	0.9851	0.0111	-1.3300	0.1840	0.9636	1.0072
floorarea	1.0000	0.0002	0.0300	0.9760	0.9995	1.0005
_cons	0.4229	0.4996	-0.7300	0.4660	0.0418	4.2835

Commercial Logistic Model

Logistic regression					Number of obs	192
					LR chi2(5)	6.92
					Prob > chi2	0.2266
Log likelihood = -121.33719					Pseudo R2	0.0277
certification	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
bigcity	0.9004	0.3228	-0.2900	0.7700	0.4459	1.8181
classa	1.4764	0.5651	1.0200	0.3090	0.6973	3.1260
floorarea	1.0000	0.0000	1.0100	0.3100	1.0000	1.0000
age	0.9910	0.0079	-1.1300	0.2580	0.9757	1.0066
core	0.8393	0.2843	-0.5200	0.6050	0.4321	1.6303
_cons	0.5969	0.2458	-1.2500	0.2100	0.2663	1.3377

Annex 7 - Consumer Surveys

Residential Consumer Surveys

In 2010, the real-estate education firm Ener-Quality (2010) released a study based on surveys taken from over 2000 respondents in the Ottawa and Greater Toronto Area (GTA). The respondents were individuals who had bought the homes they were residing in during 2009. Their survey indicated that 9 out of 10 consumers valued energy-efficiency when making their new home purchase decision, and cost-savings were cited as the primary reason. Furthermore, 62% of respondents indicated that certification was important and the biggest reason was that it was proof of energy-efficiency. If the customer did not purchase any energy-efficiency features, the biggest reason cited for this was that the real-estate agent did not mention them (EnergyQuality, 2009).

In 2007, the real-estate firm Royal Lepage conducted their "Eco-Home Survey" of 1266 Canadian households. Their survey reported that 72% of the respondents will look for a 'green improved' property for their next purchase, and 63% of respondents indicated that they would pay more for an environmentally friendly home. Of the majority who are willing to pay more, 62% of them are willing to pay between $5000 and $20,000 more for the extra features. A small minority of 8% are willing to pay beyond this (Globe and Mail, 2007).

Another Canadian-based poll was releases in 2007 by the research/polling firm Ipsos Reid on behalf of TD Canada Trust. This survey revealed that 75% of home-buyers were willing to pay a premium for a home that includes environmentally-friendly features. The biggest reason for the willingness to invest in green was the future energy-savings that these features would help bring about. Also, a slightly less important reason was the promise of a higher resale price (Newswire, 2007).

Lastly, the Canada Mortgage and Housing Corporation's 2013 survey of 500 first-time home-buyers yielded somewhat contradictory results to what has been presented above. Their research indicates that when choosing a first home the most important factors are space, commuting distances, an 'open' concept, proximity to hospitals, family, and social services. Indeed, only a small portion (16%) of first-time buyers rate energy-efficiency as being a very important factor

in their purchasing decision (CMHC, 2013, Pg.4). Therefore, perhaps at least when it comes to first-time home-purchasers, environmental factors take a back-seat to other considerations.

Commercial Surveys

For the Canadian commercial sector, a recent report produced by the Canada Green Building Council (2014) in conjunction with McGraw Hill Construction puts forward various economic arguments as to why green building demand has grown and will continue to accelerate. When it comes to client demand, 18% of respondents rated this as the most important driver, with 24% of the respondents citing this as the second or third most important. (CaGBC, 2014). Therefore, on the commercial side, at least one of the latest survey reports do indicate there is some client demand in the market which places a higher premium upon green features. However, we must also note that this study was produced by one of the biggest proponents of green buildings, and that over half of the respondents in the survey were associated with the CaGBC.

Annex 8 - Terms and Conditions of Valuation Agencies

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