Green certification and rents in the Dutch office market

Master Thesis - MSc Real Estate Studies

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Abstract

Climate change is one of the most critical global issues. Therefore, the real estate sector is transitioning to becoming more sustainable and limiting its impact on the environment. In response, the real estate sector introduced green building certification to gauge and value sustainability characteristics. However, clear empirical evidence of the financial values regarding the green rental premium is missing. Therefore the question arises: What is the relationship between green certification and the market rent for Dutch office real estate assets? A hedonic pricing model is used, whilst performing an OLS regression analysis. The main findings indicate that green-certified buildings are associated with a green rental premium of 14.9%, compared to not-green-certified office buildings. Furthermore, special attention is paid to the association between the green rental premium and location. Interestingly, no significant location effect is found. This implies that the green rental premium does not significantly increase or decrease, depending on the offices' location. All in all, this study provides critical evidence of a green rental premium for the Dutch office market, yet a significant location effect cannot be observed. This study's findings may have broad implications for real estate investors and sustainable real estate as a whole.

Keywords: Sustainable real estate, green certification, market rent, location.

Colophon

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"Master theses are preliminary materials to stimulate discussion and critical comment. The analysis and conclusions set forth are those of the author and do not indicate concurrence by the supervisor or research staff."

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1. Introduction

Climate change is one of the most critical global issues of current times. Climate change and its consequences are rapidly intensifying as global temperatures rise. Therefore, reducing CO_2 emissions is vital to ensure a sustainable future, both in ecological and economic terms (IPCC, 2021). In 2016, a global pledge was made to reduce CO_2 emissions to net-zero by 2050, profoundly impacting the construction industry (World Green Building Council, 2021). The worldwide construction industry is accountable for almost 50% of the raw material usage, 40% of the total energy consumption and 30% of the total water usage of the entire economy (Royal Institute of Chartered Surveyors, 2005). The adoption of green technology and design into the built environment can reduce the negative impacts of real estate on the environment and is a crucial step towards green buildings (Zhang et al., 2018). Therefore, a considerable effort is required for the whole real estate sector.

In response, the real estate sector introduced green building certificates. Green certification implies a voluntary market certification system that accesses the sustainable qualities of a real estate asset. Green certification aims to reduce the negative impacts of real estate on the environment, provide insight into the sustainability performance, and provide information symmetry to the market in order to value sustainable qualities (Porumb et al., 2020; Mangialardo et al., 2018). Green certification can bring multiple benefits, including lower operating costs, lower vacancy rates, faster absorption times, smaller environmental footprint, increased asset value and increased rental levels (Kok & Jennen, 2012; Zhang et al., 2018; Warren-Myers, 2012; Mangialardo et al., 2018).

However, only several studies focus on the relationship between green certification and rents within the academic field. The study conducted by Holtermans and Kok (2019) found a small[1] but significant rental premium for green-certified buildings. On the other hand, Eichholtz et al. (2010) found a significant increase in the selling price but a relatively lower green premium for rental transactions[2]. Research by Eichholtz et al. (2013)[3] & Chegut et al. (2014)[4] concluded that green certification commands a rental premium for US and UK office markets, respectively. Kok and Jennen (2012) concluded in their study that “brown” offices command lower rents[5] than green offices. Although empirical evidence is limited, we can hypothesise that green certification is positively associated with market rents.

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[1] Rental premium of 1.9%, rising to 10.1% with both energy and environmental certification
[2] Sale price premium of 16%, effective rent premium of 3 to 6%
[3] 2.1%-6.7%
[4] Chegut et al. (2014) found a rental premium for green certified building of 21.7%
[5] Up to 6.5% lower

However, there is still a debate on the exact financial values of the green rental premium (Zhang et al., 2018; Warren-Myers, 2012; Fuerst & McAllister, 2011a). Presenting concrete financial evidence can be hugely beneficial for investors in their decision-making process regarding the allocation of funds (Porumb et al., 2020). Furthermore, key evidence for some real estate markets is still missing, including the Dutch office real estate market. This knowledge gap leads us to the central research question: *"What is the relationship between green certification and the market rent for Dutch office real estate assets?".*

This research pays special attention to the location effect on green rental premiums. Several studies report that the level of the green rental premium is associated with the offices' location (Porumb et al., 2020; Eichholtz, 2010). Kok and Jennen (2012) state that the green rental premium can vary per city, as the green rental premium can be influenced by a city with a distinct office market. This may apply to major cities such as Amsterdam. Furthermore, Eichholtz et al. (2010) observed that the green premium is higher in less desirable locations than in prime locations. Consequently, they imply that location affects the level of green premium amongst office buildings. Porumb et al. (2020) concluded, in line with Eichholtz et al. (2010), that the green premium increases the farther an office is located from the city centre or CBD. Therefore, similar methods to Kok and Jennen (2012), Eichholtz et al. (2010) and Porumb et al. (2020) are incorporated to research the association between the green rental premium and location. Therefore, this thesis aims to determine if a location effect is present in the Dutch office market. All theoretical considerations are visualised in the conceptual model, as shown in figure 1[6].

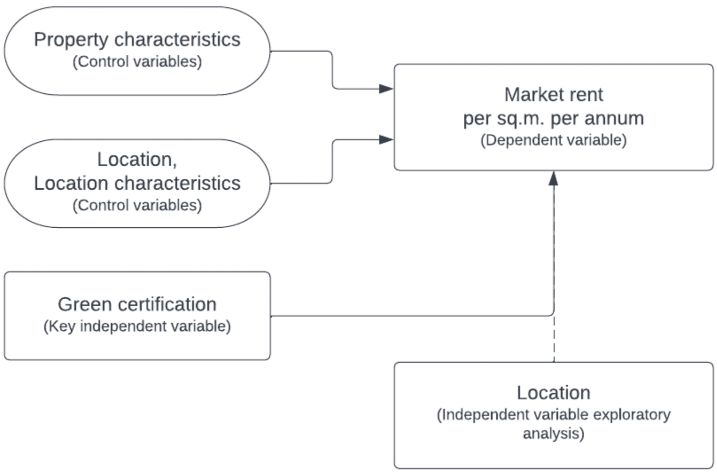

Figure 1 Conceptual model

In order to answer the central question, including the location effect, a cross-sectional dataset is used to perform a multivariate regression analysis. A multivariate regression

[6] The dotted line represents the possible interaction effect between green certification and location, as tested in the exploratory analysis

analysis is suitable for testing the relationship between market rent and green certification, which is used in similar studies (Kok and Jennen, 2012; Porumb et al., 2020; Eichholtz et al., 2010; Chegut et al., 2014). Furthermore, this research uses a hedonic pricing model[7], as this method is suited to evaluate market rents (Fuerst and McAllister, 2011; Eichholtz et al., 2010).

This research uses a detailed cross-sectional dataset, which CBRE provides. The dataset contains extensive information regarding market rents, green certification, location, location characteristics and property characteristics. The sample consists of 1221 Dutch office rental transactions. Researching rental transactions is relevant, as current research is mainly focused on appraisal value or sales prices. In addition, rental transactions are far more relevant for the Dutch office market, where around 75% of all new office transactions are rental transactions (NVM, 2021).

Initial findings suggest a significant green rental premium in the Dutch office market, corresponding with the existing literature. However, location does not seem to significantly affect the level of green premium, thus contradicting Porumb et al. (2020) findings about a location effect. Nevertheless, these findings add to the general understanding and create insights into these relatively new academic topics for different real estate markets.

The paper is structured as follows; In the second chapter, the methodology, data and study area are extensively described. The third chapter will analyse the dataset and present the research results. The results of the location effect analysis are presented in the exploratory results section. Thereafter, the fourth chapter presents the discussion, and the fifth chapter presents the conclusion.

[7] The hedonic pricing model assumes that supply is fixed, therefore the state of the overall economy is not incorporated or tested in this study

2. Methodology

2.1 Methodology design

The primary aim of this paper is to understand the relationship between green certification and market rents in the Dutch office real estate market. In order to show if green certification affects market rents, the hedonic pricing model is used[8]. Rosen (1974) pioneered the hedonic pricing model, which indicates that the value of a real estate asset is a function of its characteristics. Porumb et al. (2020) and Eichholtz et al. (2010) stated that the hedonic pricing model is the preferred method to research the determinants of rental prices, especially when changes in characteristics are involved. Therefore, the market rent is tested on green certification whilst controlling for the differences in hedonic attributes, which are added step by step to see their individual effects. Palmquist (2005) argues that rental prices are often more appropriate to estimate than sales prices, especially when non-environmental properties (i.e. internal factors) are researched, such as a buildings' sustainability aspects.

In order to test the relationship between green certification and market rents, a multivariate Ordinary Least Squares (OLS) regression is used. OLS regression shows and evaluates linear relationships between variables (Brooks & Tsolacos, 2012). However, before interpreting the results from an OLS regression, all five OLS assumptions need to be met. These five OLS assumptions are: The error term has a conditional mean of zero, constant error variance, uncorrelated errors, regressors are not correlated with the error terms and normally distributed errors. The five assumptions are tested and discussed in appendix 1. The OLS assumptions are critical to ensure that the regression results are unbiased, consistent, and efficient. Only then is the regression regarded as Best Linear Unbiased Estimator or "BLUE" (Brooks & Tsolacos, 2012).

Hereafter, the main regression model is presented. The main model is based on the previous research by Kok and Jennen (2012), Porumb et al. (2020), Chegut et al. (2014) and Zhang et al. (2018) and functions as the tool to test the hypothesis. In the main hedonic pricing model, all control variables are included, with α as the constant and ε_i as the error term.

$$lnmarketrent_i = \alpha + \beta_1 Green\ certification_i + \beta_2 Location_i + \beta_3 Submarket_i + \beta_4 Location\ characteristics_i + \beta_5 Property\ characteristics_i + \varepsilon_i$$

Here, the dependent variable is the natural log of the market rent per square meter per annum; the i stands for an individual office space. The key independent (explanatory) variable is β_1*Green certification*$_i$, which indicates if a building has green certification or not. A

[8] A hedonic pricing model can estimate each factor's (i.e. property characteristics) market price when all other (non-environmental) factors are held constant. Therefore, a price change is due to changes in characteristics, including the type of green certification, ceterus paribus, and can be tested in a regression analysis (Rosen, 1974)

significant result will indicate that market rents are indeed associated with green certification (Porumb et al., 2020; Chegut et al., 2014). After that, all control variables are added to the model step by step. $\beta_2 Location_i$ shows if the office is located in one of the five core cities in the Netherlands. β_3 Submarket shows if an office is located in a core office location (i.e. CBD[9]), as indicated in the dataset. Subsequently, β_4*Location characteristics*$_i$ represents multiple control variables; the vicinity of a train station, bar & restaurants, sports facilities and supermarkets. β_5*Property characteristics*$_i$ represents the following control variables; age, property grade, energy label, total floor area, and renovated (yes/no). After that, a subset of comparable properties is created to test the effect of green certification for identical high-end office buildings. This method is also used by Eichholtz et al. (2010) to test the effect of green certification on rental prices.

In order to test the location effect, a set of exploratory models is created to test the association between the location of the office building, green certification, and the market rent. Various studies have concluded that the rents vary depending on whether an office is located in a CBD (Evans, 2004; Zhang et al., 2018; Kok and Jennen, 2012; Porumb et al., 2020). Therefore, the location effect is tested in three different methods. Firstly, different subsets are created to test if green certification varies with location. There are two different subsets created: Core submarket and non-core submarket. This connects to the paper by Porumb et al. (2020), where the researchers used the variable "main city" to show the offices' location. Therefore, these subsets enable us to measure whether green certification has a significant result in both core and non-core locations, and if the green rental premium is indeed lower in the core cities.

Secondly, similar to the papers of Porumb et al. (2020), Kok and Jennen (2012) and Kok et al. (2011), an interaction variable is created between green certification and location. This research will use a similar method: Create two interaction variables, firstly between green certification and submarket and secondly between green certification and city. The interaction models will enable measurement and interpretation of the incremental effect of a core submarket on the green certification rental premium. A significant result suggests that the price premium incrementally increases or decreases with location. Thirdly, an interaction between green certification and Amsterdam is created to test the "Amsterdam-effect". Kok and Jennen (2012) hypothesised that the financial value of sustainable qualities might be influenced by a city having a distinct office market with major international allure.

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[9] Central Business District

2.2 Data & operationalisation

The dataset originates from CBRE Netherlands. The cross-sectional dataset is an overview of all Dutch office properties that CBRE is currently managing or has facilitated a transaction for. The raw dataset includes 20,355 observations, with an observation defined as an individual office space in the Netherlands leased by a tenant. This means that a single office building can be separated into different office spaces with multiple tenants. The cross-sectional dataset stems from May 09, 2022, meaning that variables like market rent are displayed at the price point as of May 09, 2022. As the green premium might also vary per tenure type, having a cross-sectional dataset of solely rental transactions eliminates this variation in the analysis (Addae-Dapaah & Chieh, 2011). In addition, using actual market transactions shows a more representative view of market valuation and valuing sustainable qualities.

The raw dataset contained some information which is superfluous for the regression analysis. The dataset included a limited number of non-office properties, so deviating real estate classes are dropped from the dataset. Market rent with a value of 0 and missing values was removed from the dataset, in addition to irrelevant property statuses and offices with missing bag-id's.

After cleaning the raw dataset, the descriptive statistics of the optimal sample are presented in table 1. All 1,221 office buildings have a mean market rent of €182.29 per square meter per annum. Consequently, the mean market rent differs between green-certified buildings and not green-certified buildings[10]. Furthermore, the mean market rent in a core city is also considerably higher in the core cities[11], and even higher in the core submarkets[12]. The descriptive statistics are presented in table 1 below for all variables.

Table 1 Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Market rent	1,221	182.292	93.074	13	525
Market rent (log)	1,221	5.097	.456	2.565	6.263
BREEAM Certified	1,221	.129	.336	0	1
Core city	1,221	.566	.496	0	1
Other	530	.434	.496	0	1
Amsterdam	325	.266	.441	0	1
Rotterdam	123	.100	.301	0	1
Utrecht	109	.089	.285	0	1
's-Gravenhage	74	.606	.239	0	1
Eindhoven	60	.049	.216	0	1
Core submarket	1,221	.293	.455	0	1

[10] €256,89 versus €171,21

[11] €220,49

[12] €272,99

Walktime NS station (log)	1,185	2.100	1.611	-1.609	5.150
Sportfacility distance (log)	1,183	5.961	1.048	-3.328	7.980
Supermarket distance (log)	1,183	6.189	.803	2.051	7.905
Restaurant bar distance (log)	1,182	4.922	1.154	-1.274	7.421
Age (log)	1,178	3.375	.753	0	5.919
Property grade	1,221	2.744	.791	1	4
Unknown	170	.778	.268	0	1
Grade C	663	.240	.427	0	1
Grade B	293	.543	.498	0	1
Grade A or higher	95	.139	.346	0	1
Energy label	1,221	6.093	2.439	1	9
Unknown	140	.115	.319	0	1
G	48	.039	.194	0	1
F	30	.024	.155	0	1
E	44	.036	.186	0	1
D	72	.060	.236	0	1
C	211	.173	.378	0	1
B	132	.108	.311	0	1
A	509	.417	.493	0	1
A+ - A+++	35	.027	.167	0	1
Total floor area (log)	1,221	8.441	.999	3.784	11.113
Renovation type	1,221	.031	.174	0	1

The key dependent variable, market rent, defines as the rent tenants pay in euros per square meter per annum. The market rent can indicate the established or non-established market rent, c.q. the new rental price for vacant office spaces as estimated on May 09, 2022[13]. The papers by Eichholtz et al. (2010) and Chegut et al. (2014) use a similar method, as the research includes asking rent, contract rent and effective rent. Following Eichholtz et al. (2010), both asking rents and contract rents are included in this research (i.e. established and non-established market rent). Furthermore, the continuous dependent variable is transformed to a logarithmic form to control for non-normality, heteroskedasticity, and ease of interpretation. Figure 2 visualises the natural log of market rent per square meter per annum

[13] It is unspecified in the dataset if market rent is established or non-established

in a histogram, providing insight into the data and showing that it closely follows the normal distribution[14].

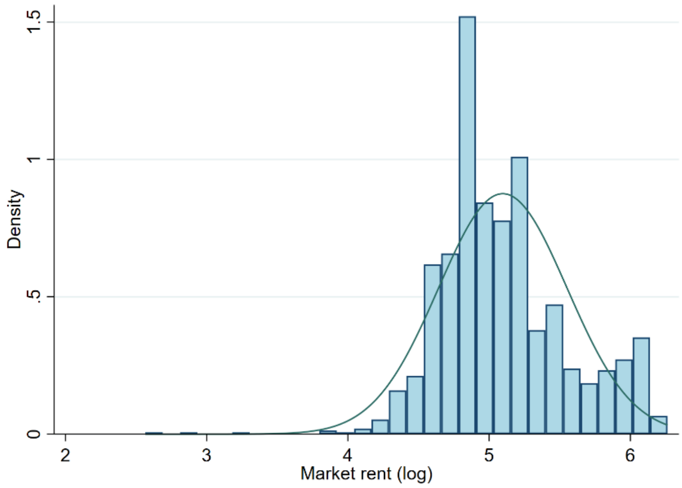

Figure 2 Market rent (log) distribution

The key independent variable, green certification, is measured if a property is BREEAM[15] certified or not. Porumb et al. (2020), Holtermans and Kok (2019) and Chegut et al. (2014) used the same method in their research by incorporating a dummy variable for green certification. The dataset consists of 158 BREEAM certified office buildings, with a non-certified group of 1063 office buildings. Table 2 displays a distribution of BREEAM certified buildings as per the location. The majority of green-certified buildings are located outside the core cities; equally, Porumb et al. (2020) found a similar distribution in their study.

Table 2 Green certification per location

	Not BREEAM certified	BREEAM certified	Total
Core city	498	32	530 (43.4%)
Non-core city	565	126	691 (56.6%)
Total city	1063 (87.1%)	158 (12.9%)	1221
Core submarket	799	64	863 (70.7%)
Non-core submarket	264	94	358 (29.3)
Total submarket	1063 (87.1%)	158 (12.9%)	1221

The raw dataset includes detailed information about the location, location characteristics and property characteristics. Most of these variables will be used as control variables for the multivariate OLS regression. All control variables are listed and operationalised in the section hereafter, including an empirical motivation on why a particular variable is included.

The first two control variables relate to the offices' location. Therefore, the first control variable is the city where the office space is located. As Kok and Jennen (2012), Palmquist

[14] Note the fat tail on the right hand side, and the three outliers with low market rents. However, there is no information or valid reasoning to exclude these from the dataset.

[15] BREEAM is the most used voluntary green building certificate in the Netherlands. As for all green certificates, BREEAM aims to increase the overall sustainability of a real estate asset. Compared to energy labels or EPC (Energy Performance Certificate), the key differentiating factor of green building certificates is that they more information about sustainability than just energy efficiency: Aspects like indoor air quality, waste management, water usage, emissions, employee wellbeing and material usage (Kok and Jennen, 2011; Chegut et al., 2014)

(2005), Evans (2004) and Fuerst & McAllister (2011) describe, location is a crucial determinant for office rent. The Dutch office market is centred around the "big four" (Amsterdam, Rotterdam, The Hague and Utrecht) and Eindhoven in terms of total stock (NVM, 2021). This method is derived from the research by Porumb et al. (2020), where the study uses the top 5 cities per country to denote the offices' location.

The following control variable is the "submarket". A submarket indicates if an office is situated in a CBD. As the location is critical in determining market rent, the location within a city is essential as rent will vary substantially between the CBD and remaining locations (Evans, 2004; Zhang et al., 2018; Kok and Jennen, 2012). CBRE (2021) described this as the location effect: Core real estate locations command a natural premium. Research by JLL (2019) qualified the core office locations in the Netherlands[16], which are then tested as a single dummy variable in the regression analysis.

The following control variables relate to the location characteristics, the first of which is the vicinity of an NS train station. As Kok and Jennen (2012) concluded, the distance to train stations significantly impacts the Dutch office market rental prices. This contributes to the accessibility of an office building. The vicinity of a NS train station is measured as the natural logarithm of walktime in minutes[17]. According to Scotchmer (1985), additional amenities are also a key determinant for real estate value. Kok and Jennen (2012) state that the walkability of offices matters when determining rent. Hence, the following control variables are included: The vicinity of sports facilities, the vicinity of supermarkets and the vicinity of bars and restaurants. These location characteristics impact the walkability of an office building and therefore correlate with the rental price. These three control variables are measured as the natural logarithm of walking distance in meters[18].

The following control variables relate to the property characteristics, the first of which is building age. Kok and Jennen (2012) and Eichholtz et al. (2010) explain that age is one of the key determinants of rent. CBRE (2021) presents similar findings; a newly constructed office building has a natural premium compared to older assets. Age is measured as the natural logarithm of 2023 - construction year[19].

The following control variable is the property grade. Kok and Jennen (2012), Eichholtz et al. (2010) and Holtermans and Kok (2019) state that quality characteristics like property grade

[16] According to JLL (2019), the following locations are regarded as a core office location the Netherlands: Amsterdam Centre; Amsterdam Zuidas; Amsterdam Zuidoost; Amsterdam Zuidoost Arena; Amsterdam IJ-Oevers; Amsterdam Sloterdijk; Amsterdam Noord; Amsterdam Amstel Station; Amsterdam West; Amsterdam Buitenveldert; Rotterdam CBD; Rotterdam Kop van Zuid; Eindhoven Strijp; Eindhoven High Tech Campus; The Hague CBD; Utrecht CBD; Utrecht Centre; Schiphol Centre and Den Bosch Paleiskwartier

[17] The variable walktime to a NS train station has 36 missing values

[18] The variable vicinity of sportfacilities, supermarkets and restaurants have 38, 38 and 39 missing values respectively

[19] The variable age has 43 missing values

influence rents. Moreover, the energy label is included in the regression analysis[20]. Zhang et al. (2018) conclude that actual energy consumption influences rents. In addition, energy consumption correlates with the level of green rental premium, as energy labels are a solid indication of actual energy consumption. This adds explanatory power to the regression model. This variable is tested as a dummy variable per energy label separately.

The following control variable is the total floor area, as floor area is a key property characteristic determining market rents (Zhang et al., 2018; Kok and Jennen, 2012; Holtermans and Kok, 2019; Eichholtz et al., 2010). The variable is included as a natural logarithm in the regression analysis. Finally, the renovated dummy control variable shows if an office building is renovated or refurbished. Kok and Jennen (2012), Chegut et al. (2014) and Eichholtz et al. (2010) use the control variable "renovated" in their studies, as renovated buildings can have positive effects on market rent.

2.3 Study area: Dutch office market

In order to better understand the contents of this research, a detailed description of the Dutch real estate office market is provided. The Dutch office market is a well-developed and established market, with a total stock of 47 million square meters in 2020 and is slowly declining over the years. As demand for office space is highest in these cities, most stock is also situated in "the big four" (Amsterdam, Rotterdam, The Hague and Utrecht) and Eindhoven. Within these cities, office districts are the most popular office location, followed by the city centres, industrial parks, living districts and rural areas.

The Dutch office market leans strongly towards renting, with 65% of all transactions being rental, with around 3 out of 4 new developments being leased out instead of sold (NVM, 2021). However, sales and rental prices can differ significantly in terms of total capital value due to short and long-term risks[21]. Rental prices have been increasing over the past decades, with the current average rental prices at around €235 per square meter in 2020, with prime locations at €450 per sqm. As for sustainability, 41% of rental objects have the energy label A. However, 31% of the national stock has an energy label D or lower, not complying with the new 2023 regulations (NVM, 2021)[22]. As for BREEAM certification, over 7.5 million square meters of office space are certified in the Netherlands, meaning around 16% of the total stock is BREEAM certified (BREEAM NL, 2020).

[20] The variable energy label has 9 missing values

[21] Ankamah-Yeboah and Rehdanz (2014) confirm the possible differences between rental and sale, especially when valuing sustainability.

[22] These regulations dictate that all Dutch office spaces need to have energy label C or better, starting from 1 January 2023. These regulations can further drive the value of green buildings

3. Results

This chapter presents all results and findings of the multivariate OLS linear regression model regarding the log-linear relationship between market rent and green certification. Firstly, a brief descriptive analysis of the data is presented. After that, the main model is tested, where location, location characteristics and property characteristics function as control variables. Finally, an exploratory model is introduced to test the location effect.

3.1 Descriptive analysis

The graphs below display several scatterplots that visualise the relationship between green certification and market rents. Studying and analysing these graphs can bring a general understanding of the association between the two variables. In figure 3, the vertical axis (y-axis) contains the natural logarithm of market rent per square meter per annum, and the horizontal axis (x-axis) contains the natural logarithm of the total floor area in square meters. The dark blue triangles and dark grey line represent the green-certified buildings, and the light blue circle and light grey line represent not green-certified buildings within the sample. The graph shows that green-certified buildings command, in general, a higher market rent for offices with the same total square footage. Moreover, as the square footage increases, the market rent of green-certified buildings becomes even higher. However, to fully understand this relationship, further regression analyses are necessary.

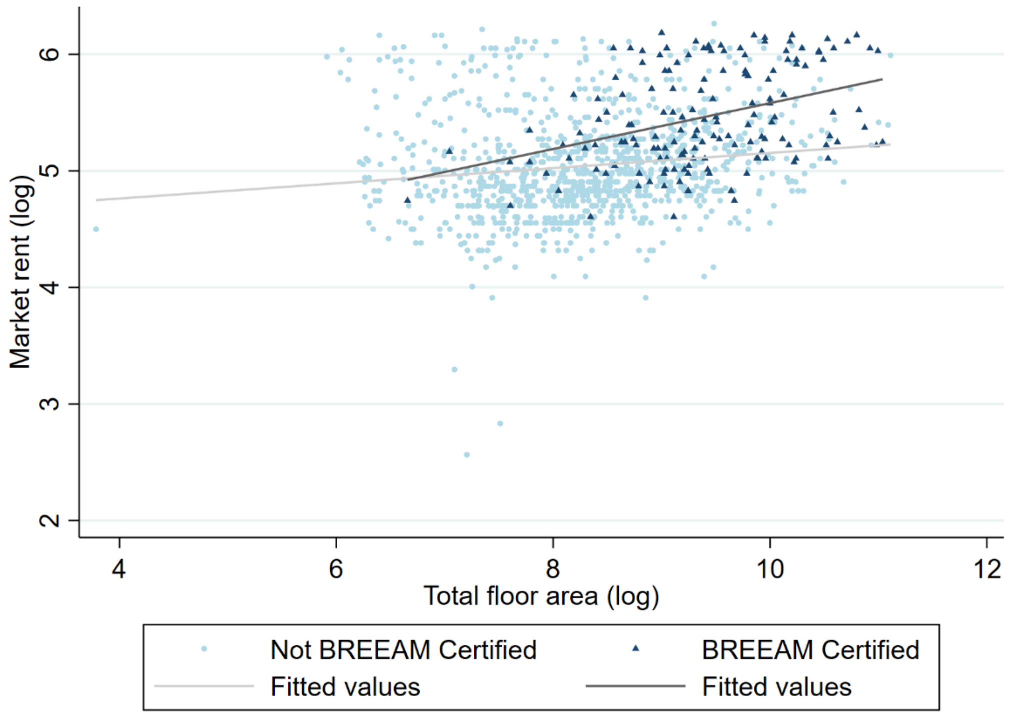

Figure 3 Scatterplot market rent (log) and total floor area (log), by BREEAM Certification

The graph below, figure 4, shows a scatterplot with the natural logarithm of market rent per square meter per annum and the office buildings per city. Once again, the triangles and dark grey lines represent the green certified office buildings, and the circles and light grey lines represent not green certified buildings[23]. The scatterplot shows a few interesting observations about the differences in market rent per city. Firstly, Amsterdam has the largest gap between green certified and not green certified office buildings regarding market rent. Although it seems that Amsterdam commands higher green rental premiums, regression model 12 will test if Amsterdam has a significantly different green rental premium. Secondly, the rental gap in market rents are relatively similar across Rotterdam, ‘s-Gravenshage, Utrecht and Eindhoven. Thirdly, the rental gap between green certified and not green certified office buildings outside the five main cities (Other) does not seem significantly larger than in the main cities, excluding Amsterdam.

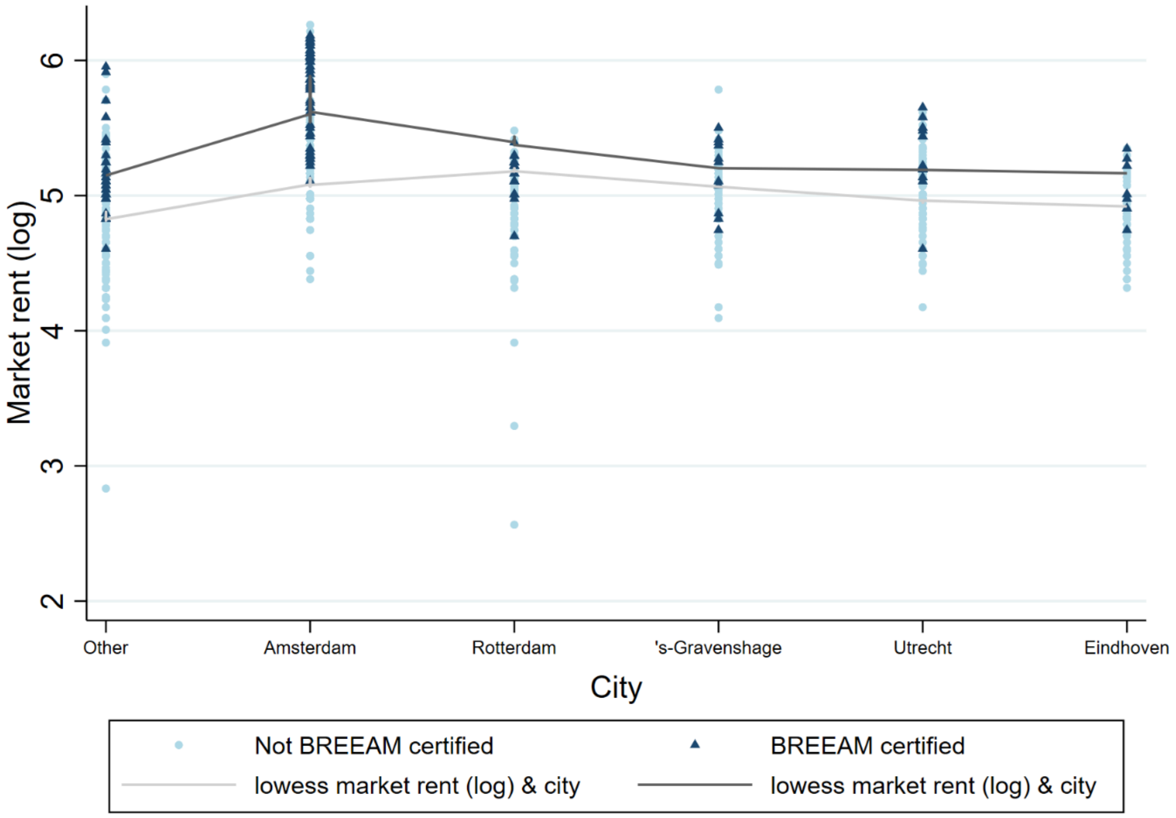

Figure 4 Scatterplot market rent (log) and city, by BREEAM certification

[23] The two lines connect the mean market rents per city, for green certified and not green certified buildings respectively. The x-axis is ordered from largest to smallest in terms of total office stock in m^2

3.2 Results

Table 3 Main regression results

	(1)	(2)	(3)	(4)	(5)	(6)
	Green certification	Location	Location characteristics	Property characteristics	Energy Label	Energy label > A & Property Grade > A
BREEAM Certified	0.416***	0.199***	0.192***	0.158***	0.139***	0.150**
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)
Core city		0.186***	0.172***	0.159***	0.151***	0.089
		(0.02)	(0.02)	(0.02)	(0.02)	(0.06)
Core submarket		0.485***	0.224***	0.181***	0.181***	0.157*
		(0.03)	(0.03)	(0.03)	(0.03)	(0.07)
Walktime NS station (log)			-0.100***	-0.095***	-0.096***	-0.126***
			(0.01)	(0.01)	(0.01)	(0.02)
Sports facility distance (log)			0.011	0.003	0.005	-0.066
			(0.01)	(0.01)	(0.01)	(0.04)
Supermarket distance (log)			-0.010	-0.006	-0.006	0.068
			(0.01)	(0.01)	(0.01)	(0.04)
Restaurant bar distance (log)			-0.038***	-0.027**	-0.024**	-0.043
			(0.01)	(0.01)	(0.01)	(0.03)
Age (log)				0.079***	0.078***	-0.051
				(0.02)	(0.02)	(0.04)
Property grade						
Grade C				-0.016	-0.002	
				(0.03)	(0.03)	
Grade B				0.078*	0.075*	
				(0.04)	(0.03)	
Grade A & Higher Grade				0.318***	0.292***	
				(0.05)	(0.05)	
Total floor area (log)				0.037***	0.038***	0.010
				(0.01)	(0.01)	(0.03)
Renovation dummy				0.204***	0.201***	0.192
				(0.06)	(0.06)	(0.15)
Energy label						
Unknown					0.098**	
					(0.04)	
G					0.062	
					(0.05)	
F					0.016	
					(0.06)	
E					0.012	
					(0.05)	
D					-0.064	
					(0.04)	
B					0.059	
					(0.03)	
A					0.083**	
					(0.03)	
A+ - A+++					0.162**	
					(0.06)	
Constant	5.043***	4.824***	5.296***	4.649***	4.576***	5.644***
	(0.01)	(0.01)	(0.08)	(0.15)	(0.15)	(0.36)
R-squared	0.094	0.448	0.532	0.558	0.568	0.768
Number of observations	1219	1217	1174	1148	1140	84

Note: The dependent variable is the natural logarithm of market rent per square meter per annum. The regression standard errors with parentheses * p<0.05, ** p<0.01 and *** p<0.001 are indicating the significance levels 5%, 1% and 0.1% respectively. The reference categories for property grade and energy label are qualified as: Unknown and Energy label C.

Table 3 shows the OLS regression results of the main model. The results relate the natural logarithm of market rent to green certification and a set of hedonic characteristics. The main model (5) is constructed by incorporating these hedonic characteristics variables step by step: First green certification (1), then the location (2), then location characteristics (3) and then property characteristics (4). After that, model 5 adds the energy label separately, resulting in a r-squared of 56.8%. This implies that, based on 1140 observations, over half of the cross-sectional variation in the natural logarithm of market rent is explained by the model. These results are comparable to Chegut et al. (2014), whilst Porumb et al. (2020) managed to explain 41.9%. As the green certification variable is a dummy variable, we cannot directly interpret this coefficient. In order to interpret this coefficient, we take the exp(β) -1 to interpret the coefficient as a percentage increase or decrease. The variables, which are transformed into a natural logarithm, can be directly interpreted as percentages.

In all five models, the log-linear relationship between market rent and green certification is positive, and statistically different from 0 at the 0.1% significance level. The coefficients of green certification reduce as more control variables are included, changing the coefficient of 0.416 in model 1 to 0.199 in model 2 when location is included. In model 3, the green certification coefficient changes further to 0.192 when location characteristics are included. Model 4 includes most property characteristics, except for the energy label, resulting in a coefficient of 0.158.

Eventually, the coefficient changes further to 0.139 in model 5 when all property characteristics are included, including the energy label. Here we observe that green certification is still significant, even when energy labels are included. A coefficient of 0.139 converts to a green rental premium of 14.9% (on average), compared to not-green certified office buildings. A green rental premium of 14.9% is in line with the existing literature and sits in the middle of the higher and lower estimates. When compared to other studies, Eichholtz et al. (2010), Fuerst & McAllister (2011) and Kok and Jennen (2012) found lower green rental premiums. On the contrary, Porumb et al. (2020) and Chegut et al. (2014) reported a larger green rental premium. Following model 5, we state that a green rental premium exists in the Dutch office market, therefore confirming the hypothesis that green certification is positively associated with market rents.

The last regression model (6) is a subset[24] of properties with identical characteristics: Energy label A or higher, and property grade A or higher. This subset enables us to analyse the effect of green certification on identical high-end office buildings. Even for high-end office buildings, green certification is statistically different from 0. This shows that even if a property has a high energy label or a high property grade, a significant green rental premium is still

[24] Model 6 contains 84 observations

present. Green certification has a coefficient of 0.150, which is slightly lower yet comparable to the findings of Eichholtz et al. (2010) for high-end office buildings.

3.3 Exploratory results: The location effect

Table 4 Exploratory regression results

	(7)	(8)	(9)	(10)	(11)	(12)
	Core city	Core submarket	Non-core submarket	Green certification*core submarket	Green certification*core city	Green certification* Amsterdam
BREEAM certified	0.154***	0.159***	0.108**	0.110**	0.126*	0.175***
City	(0.03)	(0.04)	(0.04)	(0.04)	(0.06)	(0.03)
Other	0.000					
	(.)					
Amsterdam	0.532***					0.501***
	(0.04)					(0.03)
Rotterdam	0.033					
	(0.03)					
's-Gravenhage	0.081*					
	(0.04)					
Utrecht	0.198***					
	(0.03)					
Eindhoven	-0.022					
	(0.04)					
Core submarket	-0.012					
	(0.03)					
Walktime NS station (log)	-0.039***	-0.198***	-0.089***	-0.094***	-0.122***	-0.033***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Sports facility distance (log)	0.006	-0.042**	0.040**	0.009	0.006	0.004
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Supermarket distance (log)	-0.035**	-0.115***	-0.000	-0.012	-0.003	-0.033*
	(0.01)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)
Restaurant bar distance (log)	-0.037***	-0.034*	-0.026*	-0.027**	-0.030**	-0.035***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Age (log)	0.059**	0.076*	0.103***	0.095***	0.077***	0.071***
Property grade	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
Unknown	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
Grade C	0.018	-0.252*	0.065	0.054	-0.007	0.054
	(0.03)	(0.12)	(0.03)	(0.03)	(0.03)	(0.03)
Grade B	0.078*	-0.197	0.156***	0.134***	0.072*	0.108***
	(0.03)	(0.11)	(0.04)	(0.03)	(0.04)	(0.03)
Grade A or Higher grade	0.286***	0.079	0.333***	0.358***	0.295***	0.326***
Energy label	(0.05)	(0.11)	(0.06)	(0.05)	(0.05)	(0.05)
Unknown	0.112***	0.162*	0.091*	0.108**	0.092*	0.116***
	(0.03)	(0.08)	(0.04)	(0.04)	(0.04)	(0.03)
G	0.052	0.047	0.077	0.074	0.053	0.059
	(0.05)	(0.09)	(0.06)	(0.05)	(0.05)	(0.05)
F	0.019	0.049	-0.004	-0.000	0.019	0.016
	(0.06)	(0.12)	(0.08)	(0.06)	(0.06)	(0.06)
E	-0.012	0.111	-0.012	0.024	0.006	-0.010
	(0.05)	(0.10)	(0.06)	(0.05)	(0.05)	(0.05)
D	-0.061	0.034	-0.088	-0.063	-0.058	-0.048
	(0.04)	(0.08)	(0.05)	(0.04)	(0.04)	(0.04)
C	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)
B	0.050	0.020	0.048	0.059	0.063	0.062
	(0.03)	(0.07)	(0.04)	(0.03)	(0.03)	(0.03)
A	0.077**	0.109*	0.082**	0.092***	0.088***	0.095***
	(0.02)	(0.05)	(0.03)	(0.03)	(0.03)	(0.02)
A+ - A+++	0.151**	0.157	0.154	0.178**	0.173**	0.159**
	(0.06)	(0.09)	(0.09)	(0.06)	(0.06)	(0.06)
Total floor area (log)	0.047***	0.048**	0.037**	0.039***	0.044***	0.051***

	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Renovated dummy	0.160**	0.165**	0.178	0.195***	0.231***	0.171**
	(0.05)	(0.06)	(0.13)	(0.06)	(0.06)	(0.05)
BREEAM Certified*core submarket				0.076		
				(0.06)		
BREEAM Certified*core city					0.033	
					(0.06)	
BREEAM Certified*Amsterdam						-0.032
						(0.05)
Constant	4.636***	6.041***	4.240***	4.537***	4.608***	4.535***
	(0.14)	(0.29)	(0.18)	(0.15)	(0.15)	(0.15)
R-squared	0.620	0.479	0.257	0.552	0.554	0.605
Number of observations	1136	307	815	1140	1140	1140

Note: The dependent variable is the natural logarithm of market rent per square meter per annum. The regression standard errors with parentheses * p<0.05, ** p<0.01 and *** p<0.001 are indicating the significance levels 5%, 1% and 0.1% respectively. The reference categories for property grade, energy label and city are qualified as: Unknown Energy label C and Other.

This section will elaborate on the OLS regression results of the exploratory models, as presented in table 4. The goal of the exploratory models is to test the location effect, based on the research of Porumb et al. (2020) and Kok and Jennen (2012). Model 7 includes the city variable, with the top 5 cities separately tested[25]. Model 7 shows that Amsterdam and Utrecht significantly impact the market rents, whilst Rotterdam, Eindhoven and The Hague did not provide any significant results. The green certification coefficient is 0.154, resulting in, on average, a green rental premium of 16.7%. These results are almost identical to Porumb et al. (2020), who found a green rental premium of 16.5% for offices located in a core city.

Similar to the methodology of Porumb et al. (2020), the total sample is split into two subsets: Core submarket (8) and non-core submarket (9). In model 8[26], the coefficient for green certification is significantly different from 0. As stated in model 8, the green premium is on average 17.2% in a core submarket relative to a not-green certified office building. This changes to 11.4% when an office is located in any other location but a core submarket, as stated in model 9[27]. The r-squared drops to 25.7% compared to model 8, yet the green certification variable is still significantly different from 0 at the 1% significance level. When comparing models 8 and 9, we can conclude that the green premium is higher in core locations such as a CBD when compared to non-core locations. These findings contrast with the paper by Porumb et al. (2020), who state that a green premium should increase, the farther an office is located from the CBD. Eichholtz et al. (2010) also stated that the green premium should increase the further an office is located from the CBD, but we cannot support these findings.

[25] The reference category "Other" represents all offices outside the top five cities

[26] Model 8 contains 307 observations

[27] Model 9 contains 815 observations

Model 10 tests the interaction effect between green certification and location with the entire sample[28]. The interaction effect between green certification and submarket is positive, meaning that a core submarket location has an incremental higher green premium of 7.9% relative to other office buildings. These results are in line with Porumb et al. (2020). However, the interaction effect between green certification and core city is insignificantly different from 0. An insignificant result suggests that the price premium does not significantly increase or decrease if an office building is further located from the CBD (Porumb et al., 2020). In model 11[29], the interaction between green certification and core city gives an incremental rental premium of 3.3%, but is also insignificantly different from 0. The explanatory power of models 10 and 11 is relatively high, with 55.2% and 55.4%, respectively, compared to Porumb et al. (2020).

Therefore, after analysing models 10 and 11, we can reject the presence of a location effect that core locations give a lower marginal green premium than non-core office locations. There is no evidence that the green rental premium has an incrementally different value in core cities compared to other cities. In addition, there is no evidence that the green rental premium varies significantly with distance to the CBD.

Model 12 tests the “Amsterdam-effect”; an interaction between green certification and office buildings located in Amsterdam. The explanatory power of model 12 is high, at 60.5%, compared to 36.7% of Porumb et al. (2020). However, the model shows no “Amsterdam-effect” regarding green certification rental premium. Following the same methodology and results as Kok and Jennen (2012), the interaction between green certification and Amsterdam is insignificant. Therefore, there is no evidence that the green rental premium is not incrementally different for Amsterdam compared to other cities. In other words, the green rental premium is insignificantly different from 0 in Amsterdam, further negating the location effect. The green rental premium does not increase or decrease significantly with location. Although Porumb et al. (2020) presented evidence of a location effect, this paper, just like Kok and Jennen (2012), cannot provide evidence of a location effect of green certification in the Dutch office market.

[28] 1140 observations
[29] Full sample with 1140 observations

4. Discussion

Sustainability and green certification in real estate are becoming a fascinating study field for academic researchers. This paper adds to the overall understanding of green certification in real estate. The findings regarding a green rental premium align with the existing literature, especially from highly regarded papers (Eichholtz et al., 2010; Fuerst & McAllister, 2011; Kok and Jennen, 2012; Porumb et al., 2020; Chegut et al., 2014). Although considerable research has been dedicated to green buildings, less attention has been paid to green certification and its effect on market rents (Zhang et al., 2018). As green certification incorporates more information about sustainability than just energy consumption, it enables a more thorough valuation of overall sustainability.

As aforementioned, researching rental prices instead of sales prices adds to the overall understanding of valuing sustainable qualities. Researching both green certification and rents creates valuable insights into different European markets and enables corroboration of findings between markets. Providing empirical evidence of a green rental premium in the Dutch office market can have sizeable implications for real estate investors regarding their decision-making process for fund allocations (Kok et al., 2011). In addition, using actual market transactions shows a more representative view of market valuation, when compared to government property valuations. Furthermore, these results can be generalised for office buildings across the Netherlands, as all offices are included in the regression analysis, and no selection criteria are used.

In addition, the location effect on the green premium has been scarcely researched and has not been executed for the Dutch Office market. As for the location effect, this paper presented findings that contradict the paper by Porumb et al. (2020). No incremental rental premium for offices in non-CBD locations can be observed in the Dutch office market. This paper adds to the current research on this relatively new topic and broadens the body of literature available for different European real estate markets. However, further negating the “Amsterdam-effect”, as previously done by Kok and Jennen (2012), strengthens the current body of literature. These findings negate any significantly different rental premium for green buildings in premium markets.

Despite the mentioned positive implications, this research has three main limitations. Firstly, essential information about rental contracts, vacancy rates, and certain property characteristics was missing. Contract information could provide valuable information about the duration, price indices and other agreements. This includes that established and non-established market rents are not specified in the dataset, so market rents can be either of the two options. Vacancy rates can add explanatory power to the regression models, as vacant office buildings might command a lower rent than fully occupied or highly demanded office buildings. In addition, we cannot assume that all property characteristics were incorporated in this research, which would show up in the error term or in omitted variable bias. Secondly, no detailed information on the different BREEAM certification levels was available for this research. It would be of added value to test the various BREEAM certification levels, and corroborate these findings with the existing literature. However, many studies, including Holtermans and Kok (2019) and Chegut et al. (2014), used similar methods of just a green certification dummy. This was not limiting for the research itself, as Chegut et al. (2014) state, because the different levels of BREEAM certification can be partly classified in the property grade. Thirdly, some OLS assumptions in the main model were not met. In appendix 1, the results of the OLS assumption tests are presented.

This research could be a booster for future research on green certification, location effect and market rents. This study provided insights into the Dutch office real estate market, and other studies can provide evidence for other real estate markets using similar research methods. Future studies can test the effect of various BREEAM levels on market rent in the Dutch office market. As more research on sustainability in real estate is executed and provides financially positive results, the faster the adoption of green buildings will be. Furthermore, the real estate sector can benefit from these findings, as investors can incorporate them into their decision-making in fund allocations. The financial and environmental benefits are not only positive for all stakeholders in real estate, but are most beneficial in helping the transition to a more sustainable and environmentally friendly real estate sector.

5. Conclusion

The primary aim of this paper is to understand the relationship between green certification and market rents in the Dutch office real estate market. The existing literature hypothesises that green certification is associated with higher market rents. However, for some real estate markets, clear evidence of the exact financial implications of green certification is missing. Therefore, the central research question is stated as follows: "*What is the relationship between green certification and the market rent for Dutch office real estate assets?"* In order to answer the research question, a multivariate OLS regression is performed whilst estimating on the hedonic pricing model. The findings of this research state that green certification has a significant and positive association with market rent, supporting the hypothesis. This research concluded that if an office building is green certified, the green rental premium is 14.9% per square meter per annum compared to not green certified office buildings.

Thereafter, in the exploratory analysis, special attention is paid to the green rental premium and the association with the offices' location. This paper concludes that offices in a core location command a rental premium of 17.2%, while non-core locations command a rental premium of just 11.4% per square meter per annum. Nevertheless, we can negate a significant location effect, as the interaction between green certification and location is insignificantly different from 0. Therefore, this research cannot provide evidence that the green rental premium has an incrementally different value, depending on the offices' location. As for the Amsterdam market, no significantly incremental higher or lower rental premium for green buildings is perceived. Although this is in line with the literature, it further validates the absence of a location effect in the Dutch office real estate market.

Summing up, this research provides clear evidence of a positive association between green certification and market rents, together with initial findings on the green rental premium location effect on the Dutch office market. These findings show that the green premium varies with location, yet imply that the green rental premium does not significantly increase or decrease with location. In the end, green buildings are not only beneficial for the real estate investor and the real estate sector as a whole, but most importantly, they benefit the environment.

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Appendix

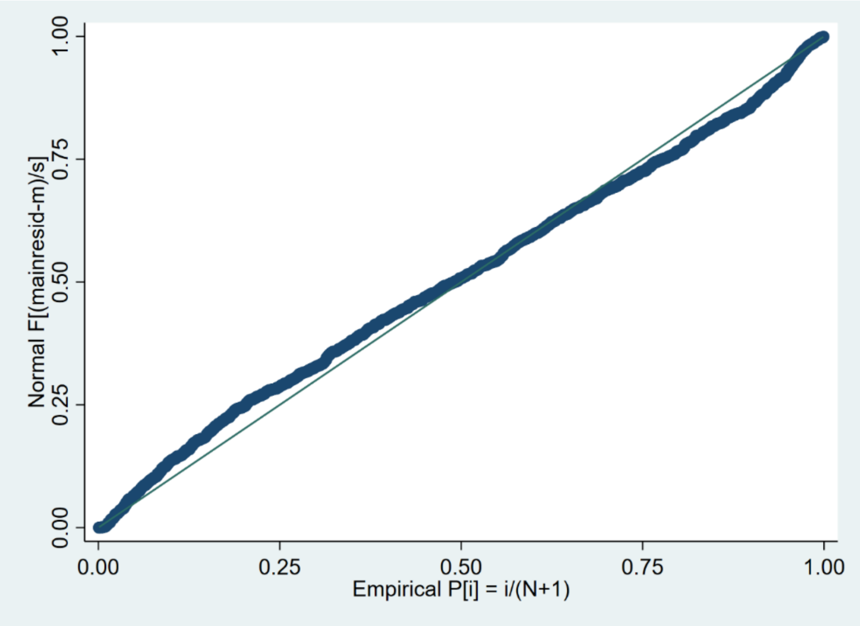
Appendix 1 Data checks

	lnmark~t	BREEAM~d	core_c~y	core_s~t	l~time~n	lnspor~e	lnsupe~e	lnrest~e	lnage	proper~m	energy~m	lntota~a	renova~m
lnmarket_r~t	1.000												
BREEAM_Cer~d	0.3067	1.000											
core_city	0.4844	0.1801	1.000										
core_subma~t	0.6287	0.2555	0.5278	1.000									
lnwalktime~n	-0.6223	-0.1895	-0.3444	-0.6699	1.000								
lnsportfac~e	-0.1147	-0.0635	-0.0791	-0.1117	0.1718	1.000							
lnsupermar~e	-0.2394	-0.0931	-0.2043	-0.2006	0.2550	0.4304	1.000						
lnrestaura~e	-0.3331	-0.1519	-0.2591	-0.3009	0.2726	0.2452	0.4709	1.000					
lnage	0.0124	-0.1263	0.1507	-0.0000	-0.0674	-0.2198	-0.2832	-0.1507	1.000				
property_g~m	-0.0100	-0.0548	0.2153	0.0642	-0.0678	-0.0929	-0.0997	-0.0525	0.5003	1.000			
energy_lab~m	0.0420	0.2055	-0.0142	0.0693	0.0256	0.1003	0.1357	0.0387	-0.4265	-0.1651	1.000		
lntotal_fl~a	0.2592	0.3625	0.1325	0.2475	-0.1715	-0.0251	-0.0108	-0.1319	-0.2350	-0.0791	0.2874	1.000	
renovation~m	0.2478	0.1136	0.1379	0.2057	-0.1607	-0.0290	-0.0778	-0.1011	0.1022	0.0475	-0.0513	0.0763	1.000

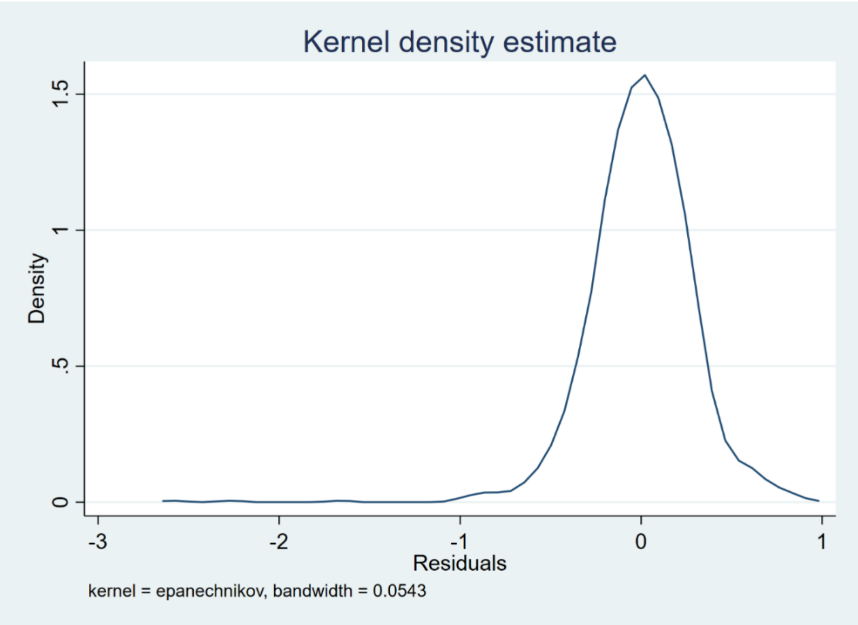
OLS assumptions model 5 (main model)

```
. regcheck
┌──────────────────────────────────────────────────────────────────────────────────────────────────────┐
   Regression assumptions:                 │ Test:                                     We seek values
├──────────────────────────────────────────────────────────────────────────────────────────────────────┤
 1) heterokedasticity problem              │ Breusch-Pagan hettest                       > 0.05
                                           │ Chi2(1): 30.953
                                           │ p-value: 0.000
├──────────────────────────────────────────────────────────────────────────────────────────────────────┤
 2) no multicollinearity problem           │ Variance inflation factor                   < 5.00
                                           │ BREEAM_Certified : 1.28
                                           │ 3.age_cat : 1.62
                                           │ 0.property_grade_num : 2.37
                                           │ 2.property_grade_num : 1.87
                                           │ 3.property_grade_num : 1.30
                                           │ 5.property_grade_num : 1.62
                                           │ 6.property_grade_num : 1.42
                                           │ 1.energy_label_num : 1.15
                                           │ 2.energy_label_num : 1.39
                                           │ 3.energy_label_num : 1.78
                                           │ 4.energy_label_num : 1.43
                                           │ core_city : 1.07
                                           │ 5.energy_label_num : 1.66
                                           │ 7.energy_label_num : 1.70
                                           │ 8.energy_label_num : 1.20
                                           │ 9.energy_label_num : 1.58
                                           │ 10.energy_label_num : 1.31
                                           │ 11.energy_label_num : 1.12
                                           │ lntotal_floor_area : 1.19
                                           │ renovation_type_num : 1.27
                                           │ core_submarket : 1.47
                                           │ lnwalktime_ns_station : 2.14
                                           │ lnsportfacility_distance : 1.10
                                           │ lnsupermarket_distance : 1.11
                                           │ lnrestaurant_bar_distance : 1.15
                                           │ 0.age_cat : 1.39
                                           │ 1.age_cat : 1.11
├──────────────────────────────────────────────────────────────────────────────────────────────────────┤
 3) residuals are not normally distributed │ Shapiro-Wilk W normality test               > 0.01
                                           │ z: 9.680
                                           │ p-value: 0.000
├──────────────────────────────────────────────────────────────────────────────────────────────────────┤
 4) specification problem                  │ Linktest                                    > 0.05
                                           │ t: 3.499
                                           │ p-value: 0.000
├──────────────────────────────────────────────────────────────────────────────────────────────────────┤
 5) functional form problem                │ Test for appropriate functional form        > 0.05
                                           │ F(3,1131):12.317
                                           │ p-value: 0.000
├──────────────────────────────────────────────────────────────────────────────────────────────────────┤
 6) no influential observations            │ Cook's distance                             < 1.00
                                           │ no distance is above the cutoff
└──────────────────────────────────────────────────────────────────────────────────────────────────────┘
```

Standardised Normal Probability plot Model 4 (main model)



Kernel Density Estimate model 1.4 (main model)



Estat vif (main model)

Variable	VIF	1/VIF
BREEAM_Cer~d	1.27	0.787348
core_city	1.59	0.628696
core_subma~t	2.33	0.428521
lnwalktime~n	1.86	0.536830
lnsportfac~e	1.30	0.772081
lnsupermar~e	1.60	0.625783

lnrestaura~e		1.42	0.703914
lnage		2.69	0.372011
property_g~m			
	2	3.45	0.289780
	3	3.01	0.331938
	4	2.42	0.412650
energy_lab~m			
	1	1.52	0.659928
	2	1.28	0.779397
	3	1.12	0.896676
	4	1.19	0.841422
	5	1.27	0.786082
	7	1.47	0.680023
	8	2.14	0.467258
	9	1.24	0.805007
lntotal_fl~a		1.33	0.749905
renovation~m		1.09	0.921414
Mean VIF		1.74	

estat imtest, white (main model)

White's test

H0: Homoskedasticity

Ha: Unrestricted heteroskedasticity

chi2(201) = 185.33

Prob > chi2 = 0.7791

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	185.33	201	0.7791
Skewness	14.40	21	0.8519
Kurtosis	2.93	1	0.0871
Total	202.66	223	0.8321

Ovtest (main model)

Ramsey RESET test for omitted variables

Omitted: Powers of fitted values of lnmarket_rent

H0: Model has no omitted variables

F(3, 1137) = 18.86

Prob > F = 0.0000

Appendix 2 Stata Syntax

```
*NAME / RES Thesis S4575881
* Start
clear all
cd "C:\Users\kajwe\OneDrive\RUG\RES Thesis\Data"
use "CBRE Office Properties 09-05-2022"
log using"C:\Users\kajwe\OneDrive\RUG\RES Thesis\Data\RES Thesis.smcl", append
ssc install regcheck
ssc install mdesc
ssc install estout

* Clean data
drop Gewijzigddoor
drop number_of_sportfacilities
drop number_of_supermarkets
drop number_of_restaurants_bars
drop walktime_subway_station
drop nearest_highway
drop nearest_supermarket
drop nearest_restaurant_bar
drop Tijdstempelvanwijziging
drop note
drop note_date
drop note_by
drop landlord
drop property_name
drop VAC2005Q4 VAC2006Q2 VAC2007Q3 VAC2007Q4 VAC2008Q1 VAC2008Q2 VAC2008Q3 VAC2008Q4 VAC2009Q1
VAC2009Q2 VAC2009Q3 VAC2009Q4 VAC2010Q1 VAC2010Q2 VAC2010Q3 VAC2010Q4 VAC2011Q1 VAC2011Q2
VAC2011Q3 VAC2011Q4 VAC2012Q1 VAC2012Q2 VAC2012Q3 VAC2012Q4 VAC2013Q1 VAC2013Q2 VAC2013Q3
VAC2013Q4 VAC2014Q1 VAC2014Q2 VAC2014Q3 VAC2014Q4 VAC2015Q1 VAC2015Q2 VAC2015Q3 VAC2015Q4
VAC2016Q1 VAC2016Q2 VAC2016Q3 VAC2016Q4 VAC2017Q1 VAC2017Q2 VAC2017Q3 VAC2017Q4 VAC2018Q1
VAC2018Q2 VAC2018Q3 VAC2018Q4 VAC2019Q1 VAC2019Q2 VAC2019Q3 VAC2019Q4 VAC2020Q1 VAC2020Q2
VAC2020Q3 VAC2020Q4 VAC2021Q1 VAC2021Q2 VAC2021Q3

drop if missing(property_id)
drop if missing(bag_id)
keep if main_use == "Office"
drop if property_status == "Pand ten onrechte opgevoerd"
drop if property_status == "Sloopvergunning verleend"
drop if market_rent <=0
replace construction_year=. if construction_year <1200

* transform data
generate lnmarket_rent=ln(market_rent)
label variable lnmarket_rent "lnmarket_rent"
generate lntotal_floor_area=ln(total_floor_area)
generate lnwalkdistance_ns_station=ln(walkdistance_ns_station)
generate lnwalktime_ns_station=ln(walktime_ns_station)
generate lnsportfacility_distance=ln(sportfacility_distance)
generate lnsupermarket_distance=ln(supermarket_distance)
generate lnrestaurant_bar_distance=ln(restaurant_bar_distance)
generate lnparking_spots=ln(parking_spots)
gen age = 2023 - construction_year
generate lnage=ln(age)

encode energy_label, generate(energy_label_num)
replace energy_label_num = 11 if missing(energy_label_num)
recode energy_label_num 11=1 10=2 9=3 8=4 7=5 6=6 5=7 1=8 2=9 3=10 4=11
recode energy_label_num 9=9 10=9 11=9
label define energy_label_num 1 "Unknown", modify
label define energy_label_num 2 "G", modify
label define energy_label_num 3 "F", modify
label define energy_label_num 4 "E", modify
label define energy_label_num 5 "D", modify
label define energy_label_num 6 "C", modify
```

```
label define energy_label_num 7 "B", modify
label define energy_label_num 8 "A", modify
label define energy_label_num 9 "A+ - A+++", modify

replace property_grade = "unknown" if missing(property_grade)
encode property_grade, generate(property_grade_num)
recode property_grade_num 5=1 3=2 2=3 1=4 4=5
recode property_grade_num 4=4 5=4
label define property_grade_num 1 "Unknown", modify
label define property_grade_num 2 "Grade C", modify
label define property_grade_num 3 "Grade B", modify
label define property_grade_num 4 "Grade A or Higher grade", modify

encode breeam_certification, generate(breeam_certification_num)
replace breeam_certification_num = 0 if missing(breeam_certification_num)
tab breeam_certification_num, gen(breaam_dum)
rename breaam_dum1 Not_BREEAM_Certified
rename breaam_dum2 BREEAM_Certified
*BREEAM Dummy
replace breeam_certification = "Niet gecertificeerd" if missing(breeam_certification)
tab breeam_certification, gen(breeam_dummy)

recode construction_year 0/1940 = 0 1940/1960 = 1 1961/1980 =2 1981/2000 = 3 2001/2022 = 4, generate(age_num)
recode age_num (0 = 0 "Pre 1940")(1 = 1 "1941-1960") (2 = 2 "1961-1980") (3 = 3 "1981-2000") (4 = 4 "2001-now"),
gen(age_cat)

label define breeam_certification_num 0 "Not_BREEAM_certified", modify
label define breeam_certification_num 1 "BREEAM_Certified", modify
encode renovation_type, generate(renovation_type_num)
replace renovation_type_num = 0 if missing(renovation_type_num)
replace renovation_type_num = 1 if renovation_type == "Refurbishment" | renovation_type == "Renovation" | renovation_type
== "extraction To be announced"
label define renovation_type_num 1 "Renovation/Refurbishment", modify

* transform location
generate core_city = 0
replace core_city = 1 if city == "Amsterdam"
replace core_city = 1 if city == "Rotterdam"
replace core_city = 1 if city == "Utrecht"
replace core_city = 1 if city == "'s-Gravenhage"
replace core_city = 1 if city == "Eindhoven"

encode city, generate(by_city)
replace by_city = 0
replace by_city = 1 if city == "Amsterdam"
replace by_city = 2 if city == "Rotterdam"
replace by_city = 3 if city == "'s-Gravenhage"
replace by_city = 4 if city == "Utrecht"
replace by_city = 5 if city == "Eindhoven"
label define by_city 0 "Other", modify
label define by_city 1 "Amsterdam", modify
label define by_city 2 "Rotterdam", modify
label define by_city 3 "'s-Gravenhage", modify
label define by_city 4 "Utrecht", modify
label define by_city 5 "Eindhoven", modify

generate core_submarket = 0
replace core_submarket = 1 if submarket1 == "Amsterdam Centre" | submarket1 == "Amsterdam Zuidas" | submarket1 ==
"Amsterdam Zuidoost" | submarket1 == "Amsterdam Zuidoost Arena" | submarket1 == "Amsterdam IJ-Oevers" | submarket1 ==
"Amsterdam Sloterdijk" | submarket1 == "Amsterdam Noord" | submarket1 == "Amsterdam Amstel Station" | submarket1 ==
"Amsterdam West" | submarket1 == "Amsterdam Buitenveldert"
replace core_submarket = 1 if submarket1 == "Rotterdam CBD" | submarket1 == "Rotterdam Kop van Zuid" | submarket1 ==
"Eindhoven Strijp" | submarket1 == "Eindhoven High Tech Campus" | submarket1 == "The Hague CBD" | submarket1 ==
"Utrecht CBD" | submarket1 == "Utrecht Centre"| submarket1 == "Schiphol Centre" | submarket1 == "Den Bosch Paleiskwartier"

* Check data
```

```
summarize market_rent lnmarket_rent BREEAM_Certified core_city core_submarket lnwalktime_ns_station
lnsportfacility_distance lnsupermarket_distance lnrestaurant_bar_distance age lnage property_grade_num energy_label_num
lntotal_floor_area renovation_type_num
summarize market_rent if core_submarket
summarize market_rent if core_city
summarize market_rent if Not_BREEAM_Certified
summarize market_rent if BREEAM_Certified
summarize market_rent if core_city & BREEAM_Certified
summarize market_rent if core_submarket & BREEAM_Certified
tab core_city BREEAM_Certified
tab core_submarket BREEAM_Certified
tab core_city core_submarket
pwcorr lnmarket_rent BREEAM_Certified core_city core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance lnage property_grade_num energy_label_num lntotal_floor_area
renovation_type_num

* Visualize data
histogram lnmarket_rent, density normal
histogram lntotal_floor_area, density normal
graph twoway (lfit lnmarket_rent breeam_certification_num) (scatter lnmarket_rent breeam_certification_num)
twoway scatter lnmarket_rent lntotal_floor_area if breeam_certification_num == 0 || scatter lnmarket_rent lntotal_floor_area if
breeam_certification_num == 1 || (lfit lnmarket_rent lntotal_floor_area if breeam_certification_num == 0) (lfit lnmarket_rent
lntotal_floor_area if breeam_certification_num == 1), ytitle(lnmarket_rent)
twoway scatter lnmarket_rent lntotal_floor_area || lfit lnmarket_rent lntotal_floor_area, by(breeam_certification_num, legend(on))
graph twoway (lfit lnmarket_rent breeam_certification_num) (scatter lnmarket_rent breeam_certification_num),
ytitle(lnmarket_rent)
scatter lnmarket_rent breeam_certification_num
twoway scatter lnmarket_rent by_city if breeam_certification_num == 0 || scatter lnmarket_rent by_city if
breeam_certification_num == 1 || (lowess lnmarket_rent by_city if breeam_certification_num == 0) (lowess lnmarket_rent by_city
if breeam_certification_num == 1), ytitle(lnmarket_rent)

* Main models 1-6
regress lnmarket_rent BREEAM_Certified
estimates store m1, title((1))
regress lnmarket_rent BREEAM_Certified core_city core_submarket
estimates store m2, title((2))
regress lnmarket_rent BREEAM_Certified core_city core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance
estimates store m3, title((3))
regress lnmarket_rent BREEAM_Certified core_city core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance lnage ib1.property_grade_num lntotal_floor_area renovation_type_num
estimates store m4, title((4))
regress lnmarket_rent BREEAM_Certified core_city core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area
renovation_type_num
estimates store m5, title((5))
regress lnmarket_rent BREEAM_Certified core_city core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance lnage lntotal_floor_area renovation_type_num if energy_label_num > 5 &
property_grade_num == 4
estimates store m6, title((6))
estout m1 m2 m3 m4 m5 m6, cells(b(star fmt(3)) se(par fmt(2)))  ///
   legend label varlabels(_cons constant)              ///
   stats(r2 df_r)

* Exploratory models 7-1
regress lnmarket_rent BREEAM_Certified i.by_city core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area
renovation_type_num
estimates store m7, title((7))
regress lnmarket_rent BREEAM_Certified lnwalktime_ns_station lnsportfacility_distance lnsupermarket_distance
lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area renovation_type_num if
core_submarket == 1
estimates store m8, title((8))
regress lnmarket_rent BREEAM_Certified lnwalktime_ns_station lnsportfacility_distance lnsupermarket_distance
lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area renovation_type_num if
core_submarket == 0
```

```
estimates store m9, title((9))
regress lnmarket_rent i.BREEAM_Certified##i.core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area
renovation_type_num
estimates store m10, title((10))
regress lnmarket_rent i.BREEAM_Certified##i.core_city lnwalktime_ns_station lnsportfacility_distance lnsupermarket_distance
lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area renovation_type_num
estimates store m11, title((11))
regress lnmarket_rent i.BREEAM_Certified##1.by_city lnwalktime_ns_station lnsportfacility_distance lnsupermarket_distance
lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area renovation_type_num
estimates store m12, title((12))
estout m7 m8 m9 m10 m11 m12, cells(b(star fmt(3)) se(par fmt(2)))  ///
   legend label varlabels(_cons constant)             ///
   stats(r2 df_r)

regress lnmarket_rent BREEAM_Certified i.by_city i.core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area
renovation_type_num
* OLS assumptions main model
regress lnmarket_rent BREEAM_Certified core_city core_submarket lnwalktime_ns_station lnsportfacility_distance
lnsupermarket_distance lnrestaurant_bar_distance lnage ib1.property_grade_num ib6.energy_label_num lntotal_floor_area
renovation_type_num
predict mainresid, resid
scatter lnmarket_rent mainresid
qnorm mainresid
estat vif
estat hettest
estat imtest, white
ovtest
kdensity mainresid
pnorm mainresid
regcheck
*
log close
translate"C:\Users\kajwe\OneDrive\RUG\RES Thesis\Data\RES Thesis.smcl" "C:\Users\kajwe\OneDrive\RUG\RES
Thesis\Data\RES Thesis.smcl.pdf"
```