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Master Thesis MSc. Financial Economics

THE CAPITALIZATION OF SUSTAINABILITY WITHIN THE DUTCH OFFICE MARKET

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Name: Rick Ruiter

Student Number: 415565

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Supervisor: dr. J. van Haaren

Second Assessor: Prof. dr. (Frank) F.G. van Oort

Abstract

This paper examines the effect of energy efficiency on the prices of both rental and sales transactions within the office property market in the Netherlands. This is considered one of the most tangible elements of sustainability since it offers a crucial opportunity for conserving resources. The existing literature provides strong evidence for the claim that sustainability translates into positive price premiums. While the literature predominantly examines the green premium using the hedonic pricing method, the approach to control for one of the most important price determinants, location, did not find any consensus yet. This study pioneers by including urbanization into this research, resulting in a more parsimonious model. Overall, the findings in this paper provide strong evidence to affirm the prevailing green premium, provide no persuasive evidence – but does show potential – for a moderating effect of the prospective label-C restriction announced in October 2016, and shows the effectiveness of urbanization as an alternate approach to overcome common identification issues. The findings of this paper are relevant for investors that are confronted with required investments in energy improvements, as the importance of energy efficiency is bound to increase following stricter environmental regulations. For policymakers, the results provide an indication of the effectiveness of the EPC labeling system and further guidelines for accelerating the greening of the built environment.

TABLE OF CONTENTS

1 INTRODUCTION

Ahead of the Madrid climate conference of 2019 (COP 25), the European Parliament declared a global climate and environmental emergency (European Parliament, 2019). Given this situation, EU member states are forced to reduce greenhouse gas emissions by 55% in 2030. In order to achieve this ambitious goal and strengthen the ability to cope with the consequences of climate change, the gap between current policies and the required actions for the Madrid objectives must be closed. That is, accelerating the usage of emission-neutral energy technologies, increasing energy efficiency, limiting the non-CO2 greenhouse gasses, and changing land-use trends (COMMIT & CD-LINKS, 2018)[1]. For that reason, the Netherlands is at the dawn of drastic reformations of the energy structure; the complete built environment in the Netherlands is to be cut off from natural gas by 2050. That implicates increasing the sustainability of over seven million houses and one million buildings in respectively the residential and commercial real estate sector (Ministry of Economic Affairs and Climate Policy, 2019).

Increasing the energy efficiency of the built environment is important in matters of environmental sustainability. Overall, real estate activities account for over 20 percent of world greenhouse gas emissions (World Economic Forum, 2016). The impact of energy costs has a direct impact on both tenants and building owners, affecting everyday life throughout society. Therefore, the transition is not merely bounded to reforming energy but can be extended into broader terms, i.e. a societal transition. The importance of the design and operation of commercial real estate in energy conservation can be explained by the fact that it is the single biggest and most manageable expense in the provision of an office building; taking account for 30 percent of operating expense in a typical office building (Eichholtz, Kok, & Quigley, 2010). Moreover, around 75 percent of the European property sector is energy inefficient[2]. It has been argued that to decarbonize the real estate sector to modern, low-carbon levels with the current one percent yearly renovation rate, would take somewhere close to a century (Zancanella, Bertoldi, & Boza-Kiss, 2018).

The Dutch awareness of this fact is charted by the rising attention on green rating systems for buildings, set by both the government and the market. On October 28, 2016, the

[1] COMMIT & CD-LINKS projects is a research initiative where more than 10 modelling teams around the world are collaborating in order to support international climate policies.

[2] This information was sourced from the Eurostat website: https://ec.europa.eu/eurostat

Dutch government announced a new regulation, forcing all office buildings to increase their energy performance to a regulated threshold by 2023 (Ministry of the Interior and Kingdom Relations, 2016). At that moment only half of the Dutch office space met the prospective energy restriction, making 44 percent unserviceable in the future (RVO, 2019). As of today, this number of unleasable office spaces already decreased to 32 percent.

However, in recent literature, the research on how sustainability labeling affects the value of Dutch office buildings has so far been limited or out-dated. Energy efficiency is an omnipresent theme in sustainability and considered as the most tangible indicator of sustainable investments in the market of commercial real estate (Kok & Jennen, 2012). Since the economic rationale of sustainability is not scientifically robust, it is uncertain how far to implement investments in the energy efficiency of offices. Considering the increased interest in the energy transition, the enormous amount of money involved in this transition and future restrictions on energy labels of offices implies that knowledge on the value of energy efficiency is adequately relevant. This leads to the following research question:

What are the effects of energy efficiency on the price of rental and sales transactions of Dutch office buildings?

This study proceeds with exploring the existing literature that examines the market capitalization of sustainability and energy efficiency in the international real estate markets of commercial assets and office buildings specifically. This provides insights into the methods used and more importantly, outlines the importance and relevance of the research question that this paper has set out to answer. The methodology and variables used in this paper build upon the specifications of the hedonic pricing methods that are found in the literature. The hedonic baseline model examines the relationship between the prices of both rental and sales transactions, and the energy efficiency, denoted by the corresponding EPCs or the continuous scores of the Energy Index. After the regression analyses are performed, several alternations will be made to the models to check the robustness of the results across the various specifications.

This study adds a new perspective by bringing all learnings from the existing studies together and finds supporting evidence that investors and tenants are willing to pay a significant premium for green buildings. More specifically, the results indicate that buildings that are labeled C or higher command rental and sales premia of respectively 7.7% and 7.6% compared to their energy-inefficient opposites. In terms of EPI, a 10% increase in energy efficiency leads to an increase of 7.1% and 4.8% in rental and sales prices respectively. Assessing the label categories individually results in less persuasive evidence. However, it may be an interesting indicator of a potential sorting effect. That is, the trade-off between the pros and cons of energy efficiency is most actively effectuated by owners and tenants of offices labeled C, D and E. While firms that are heavily driven by CSR purposes may always sort themself in the best buildings labeled with A and B, and business that do not care at all are left with the worst energy performing buildings (labeled with F and G). All in all, the results that are found are aligned with the afore-set expectations.

The remainder of the paper is structured as follows. Firstly, the main concepts and theories will be discussed in the theoretical framework, followed by the review of the existing literature, in which methodologies and past findings will be identified. Third, the hypotheses will be constructed, after which the modeling strategy, used variables, and the identification issues will be discussed in continuation. Next, section 5 will elaborate upon the sample matching process along with the descriptive statistics. Section 6 contains the obtained empirical results, upon which the results will be discussed in light of the formulated hypotheses. Conclusively, the last section presents the conclusions, limitations, and suggestions for future research.

2 THEORETICAL BACKGROUND AND RELATED LITERATURE

2.1 Sustainability in the Office Property Market

In the last decade, keywords such as sustainability, green building, and energy efficiency have gained momentum in the office property markets. Businesses are encouraged to frame their operational governance in terms of years and decades in order to create sustainable value. Inherent to this green movement is the corporate social responsibility framework (CSR), that has become a normative standard for decision taking on the choice of inputs, internal processes, and external relations (Thompson & Ke, 2012). For progressively more and more investors social responsible characteristics have become an investment criterion, i.e. incorporating social responsible screens into their investment process. According to the Social Investment Forum (2018), one in four dollars of the total US assets under professional management is allocated to socially screened portfolios. Although the investments in social responsible assets have emerged dramatically in recent years, the debate on the financial performance of such ethical investments still did not find any consensus (Wen, 2009).

2.1.1 *The link between sustainability and asset value*

In the literature, several factors are argued to fuel the potential financial outperformance of well-established CSR policies, i.e. improved corporate reputation, reduced intrusion from activists and governmental organizations, decreased threat of regulation, and higher profitability through lower input costs and increased employee productivity (Eichholtz, Kok, & Quigley, 2010). The latter two display the most tangible aspects of CSR in the market of commercial real estate. In addition, real estate owners are becoming more conscious that the potential value of energy efficiency is more profound than solely the cost-reduction perspective. Tenants not only assess the price tag of their buildings but besides focus on how their real estate properties affect their business activities as a whole. As such, RICS (2005) postulates that green buildings are more likely to retain value over their life cycle. They define green buildings as properties that minimize their impact on the environment while focusing on optimizing a healthy indoor ecosystem for the end-users. In this context, the economic rationale or investing in green buildings can be explained by viewing several distinct perspectives (Eichholtz, Kok, & Quigley, 2010).

First, investing in energy efficiency lowers the operational costs for the tenant through reduced energy consumption, insures against future energy price changes, and reduces greenhouse gas emissions. Meaning, among others, that tenants of more energy-efficient buildings are able to pay higher base rents to the property owner.

Second, leasing space in an energy-efficient building might be beneficial for the corporate reputation and its relations with different stakeholders, i.e. investors, the public, and employees. Firms may carry out a signal of social awareness and superior social responsibility of the tenants by establishing their business in a green office. Consequently, firms that value being green may be willing to pay a premium for energy-efficient buildings with a renowned green image.

Third, the quality of the indoor environment might have an impact on the employees' health, affecting, *inter alia*, their productivity. Sing et al. (2010) address this relation between improved indoor environmental quality (e.g. air quality, temperature, humidity, air-circulation) and perceived health and productivity in occupants who moved from conventional to green office buildings. They find that the productivity of employees increases with approximately 2.6 percent in a green office compared to a 'non-green' office. Moreover, Sing et al. state that improved indoor environmental quality contributes to reductions in absenteeism and work hours affected by asthma, depressions, stress, and respiratory allergies. In line with these results, CBRE[3] (2017) find that employees perform 10 percent better in a healthy working environment. Due to the putative health and productivity costs that are imposed by poor indoor environmental quality, firms might be willing to pay premia for offices where indoor environmental quality is higher.

Fourth, the ongoing debate on global warming and the corporate social responsibilities of the various parties of society involved to save energy increases the likelihood of future policies that make tenants and investors want to avoid energy-inefficient buildings. Given these expectations, it is likely that the preference for sustainable buildings will increase even further in the near future, meaning that energy-efficient buildings could have longer economic lives relative to conventional buildings. In the Netherlands, such policies are already set in place and the most energy-wasting offices will be banned from 2023 on (Ministry of Economic Affairs and Climate Policy, 2019). Therefore, green buildings are likely to be less sensitive to environmental risk and better marketable resulting in lower risk premia and improved asset value. Orlitzky and Benjamin (2001) analyzed the effect of corporate social performance on the overall firm risk. Their findings support the theoretical argument that the higher the firm's

[3] CBRE Research is an integrated community of preeminent researchers who provide real estate market research, econometric forecasting and corporate- and public-sector strategies.

social reputation the lower its financial risk. If their results can be extrapolated to the real estate office market, sustainability may be rewarded with higher valuations through a lower cost of capital. Meaning, that even by putting aside potential benefits through higher spot rents, building green could be relatively more valuable.

2.1.2 *Certification systems in the international office market*

Certification programs provide prospective buyers and tenants with credible signals or labels on the energy performance of their assets through the quantification of sustainable performance characteristics. The assessment methods, scope, and criteria of such certification systems concerning the energy or environmental performance of commercial real estate diverge significantly. Whereas some systems focus solely on energy efficiency, other programs assess a much wider range of environmental and sustainability factors. Also, the implementation of energy labeling takes different forms across countries. Whereas the disclosure of energy performance certificates (EPCs) for buildings is mandatory in the European Union, the US labeling system is built upon a market-driven approach through voluntary certification. Table 2.1 provides the breakdown of the different assessment criteria, origin, disclosure policies, and related certification expenses of the rating systems that will be mentioned in the next section.

Table 2.1 – Breakdown of different methods in certification systems

	BREEAM	LEED	Energy Star	Green Star	NABERS	EPC
Origin	UK	US	US	Australia	Australia	EU
Categories						
Energy efficiency	x[1]	x[1]	x[1]	x[3]	x[3]	x[4]
Transport	x[1]			x[3]		
Water	x[1]	x[1]		x[3]	x[3]	
Ecology	x[1]	x[1]				
Land use	x[1]	x[1]		x[3]		
Materials & waste	x[1]	x[1]		x[3]	x[3]	
Health and well being	x[1]	x[1]				
Pollution	x[1]					
Innovation		x[1]		x[3]		
Disclosure	Voluntary[2]	Voluntary[2]	Voluntary[2]	Voluntary[3]	Voluntary[3]	Mandatory[4]
Certification costs	High[2]	High[2]	Free[2]	Moderate[2]	Low[2]	Low[4]

Sources: [1]Yiing et al. (2010); [2]Own research; [3]Bose (2010); [4]Van Eck (2016)

Moreover, this paper zooms on sustainability labeling in the Dutch office market. In 2003 the EU introduced the EPBD[4], which mandates member states to implement a system of energy labeling for building stock. This European energy-saving direction is building-related and comprises information on the amount of energy that, in normal-usage of the building stock, is necessary. It was until 2008 that the EPCs were first introduced in the Netherlands, where the energy efficiency certification only became mandatory for commercial real estate in 2015. Furthermore, the Dutch government announced various prospective regulation in order to green the built environment. For the commercial real estate market this imposes a mandatory energy performance that meet the requirements for a C-label as of 2023, an A-label in 2030, and complete energy neutrality in 2050 (Ministry of the Interior and Kingdom Relations, 2016).

The information is based on a calculation related to energy usage for heating, lighting, ventilation, and cooling. The energy performance is benchmarked in an energy-index (EI) and standardized energy classes and are, for the purpose of this paper, grouped into green and non-green buildings as presented in Table 2.2. Buildings are ranked from efficient (A) to inefficient (G), providing concise information on the potential sustainability retrofit opportunities. The energy label is valid for 10 years upon the date of issuance.

Table 2.2 – Energy classes for commercial real estate

Green Buildings					Non-green Buildings			
A++	A++	A	B	C	D	E	F	G
<0.5	0.51 - 0.70	0.71 - 1.05	1.06 - 1.15	1.16 - 1.30	1.31 - 1.45	1.46 - 1.60	1.61 - 1.75	>1.75

Source: http:www.rvo.nl

2.1.3 *Methodology considerations*

Hedonic regression modeling is a widely adopted methodology for identifying price determinants in the literature of real estate. The hedonic pricing model estimates the price factors according to the premise that the price of the heterogenous good (e.g. buildings) is affected by both internal characteristics and external factors. This method is often applied when regressing prices of real estate on a set of intrinsic characteristics and location factors. However, the application of this revealed preference method in the segment of office buildings is scarcer than for residential housing. This can be explained by the notoriously difficult process

[4] Energy Performance Building Directive (EPBD) is a legislative framework covering a broad range of policies and supportive measures to aid national EU governments boosting energy performance of buildings.

of gathering the required data concerning property characteristics in the private sensitive field of office buildings (Kok & Jennen, 2012). Moreover, data for office buildings tend to be less reliable (Nappi-Choulet & Décamps, 2013). That the hedonic literature on the effects of green premiums for rent and capital values is mainly concentrated in the US, is due to the availability of the extensive CoStar database of office buildings (which covers roughly 80 percent of all transactions in the US). The scarcity of literature in Europe, and the Netherlands in specific, is due to a lack of such a centralized database. Given this context, in this research, the potential data and modeling issues have to be anticipated when defining the methodology. That is, the extent to which the preferred methodology derived from the literature can be applied may be restricted by the data.

2.2 Related Literature

The environmental externalities of the built environment captured attention throughout the real estate sector. However, the environmental impact of the energy efficiency of commercial real estate has become mostly a topic of discussion, rather than being subject to wide rigorous analysis by urban scholars. This is mostly due to the fact that the real estate market exhibits one of the most opaque information systems in the world, i.e. access to local market information on the energy performance of commercial properties is limited (Kok & Jennen, 2012). Therefore, the commercial real estate sector is increasingly demanding for more transparency on energy efficiency through e.g. federal programs. Policymakers and regulators have responded to this challenge by setting up environmental building certification programs, boosting the literature on the price premium of energy efficiency (Mudgal et al., 2013). The studies that investigate whether obtaining sustainable building certification entails a premium for commercial real estate, roughly find significant positive premiums. Table 2.2 summarizes the effects found in academia.

The most widely quoted scholars among these studies were Miller et al. (2008), who were one of the first extrapolate the literature on residential energy efficiency to the commercial sector of office buildings. They control for differences within their sample by including several hedonic variables like size, age, location and district in their model. Miller et al. (2008) found significant premia in sales value of roughly 10% and 6% for LEED and Energy star respectively. While the rigorous studies that followed all used econometric models to examine the price effects of sustainability certifications, they widely differ in terms of model specification, choice of explanatory variables, and sampling. Moreover, due to the private sensitive nature of the sector and the complexity of defining and quantifying sustainability, there is a bifurcation in the choice of sustainability variables, i.e. focussing on solely energy efficiency or a broader definition of sustainability.

The literature review begins with a concise exploration of international literature to learn from existing methods and determine the further direction of this study. In continuation, the differences between observed premia of sales and rental transactions, and the stationarity of the premia will be discussed. Lastly, the review zooms on the price effects of energy efficiency in the Dutch office market and touches upon the role of location in this issue.

2.2.1 *Learnings from foreign studies*

The majority of the literature that aims to identify the effect of environmental certification on the value of office buildings draws upon the extensive CoStar database of US properties. The most important learnings from the US body of literature will be briefly mentioned, starting with Wiley, Benefield and Johnson (2010). They were among the first wave of urban scholars to explore this field. Using a hedonic approach, Wiley et al. (2010) assessed the effects on rent, occupancy rate and sales value of sustainable certification systems for class A buildings. In their results, they estimated premia of 1255 €/m^2 (original: 130 \$/ft^2) and 290 €/m^2 (original: 30 \$/ft^2) for LEED and Energy Star certified offices respectively. In terms of rental contracts, they present premia ranging from roughly 15-17% for LEED and 7-9% for Energy Star. To this end, it has to be noted that these results need to be interpreted with some caution. Namely, a key issue in their paper is the control for location. They analyze the premium price effects for certified office properties relative to non-certified offices within the same metropolitan area while ignoring controls for micro-locational effects. Fuerst and McAllister (2011b) commented on this by stating that sustainable offices may tend to be located in higher quality districts within the same metropolitan area, therefore, their results may be biased. That is, observed premia may include a location as well as a certification premium. Moreover, Wiley et al. (2010) do not explicitly mention their sample size nor period. However, from their summary statistics, it can be inferred that their observation in terms of rental and sales transactions were extremely low for both LEED and Energy Star. In order to deal with the location bias, borrowing from the literature on commercial real estate, Reichard et al. (2012) deviated from the traditional hedonic framework. The authors applied both fixed effects (FE) and difference in difference (DID) techniques, using a unique dataset with observations ex-ante and ex-post certification for the same building. This allowed them to control for micro-locational effects within the same metropolitan area.

Other than North America, studies on value premiums for sustainability certifications have been performed in the UK (Fuerst & McAllister, 2011c; Chegut, Eichholtz, & Kok, 2013), Sweden (Bonde & Song, 2013), Australia (Newell, MacFarlane, & Walker, 2014; Gabe & Rehm, 2014), France (Nappi-Choulet & Décamps, 2013), and the Netherlands (Kok & Jennen, 2012). Albeit the cross-country differences, the findings reach a general consensus in regard to the green premiums in the US, with some exceptions (Fuerst & McAllister, 2011c; Bonde & Song, 2013; Gabe & Rehm, 2014).

On the contrary, Fuerst and McAllister (2011c), Bonde and Song (2013), and Gabe and Rehm (2014) present an alternate narrative to the general consensus that prospective tenants are willing to pay significant price premiums for green offices. Assessing not only UK offices, but also the industrial and retail sector, Fuerst and McAllister (2011c) do not find any significant evidence for green premiums. They conjecture that EPCs fail to financially incentivize UK market players to invest in energy efficiency improvements. However, their choice to deliberately omit controls for micro-locational differences is quite remarkable. They argue that there is no evidence that green offices are located in more beneficial regions compared to non-green offices. In addition, the results of Bonde and Song (2013) indicate that energy performance has no impact on the market value of Swedish buildings. However, they address the complications that may arise when relying on appraisals rather than transactional data. Bonde and Song argue that appraisers are likely to smooth their valuations over time and that it is complex to account for asset heterogeneity in their valuations. They conclude that using market transaction prices would have increased the robustness of their results as it would reveal the true green premium, providing guidelines for further studies. Furthermore, Gabe and Rehm (2014) use their lack of significant rent premiums from leasing contracts in central Sydney to content the general assumption that tenants are willing to pay green premiums. They state that their results may indicate a lack of financial salience and the absence of enforceable federal programs with regard to energy and greenhouse gas efficiency. Moreover, Gabe and Rehm address the complication of using asking rent as a dependent variable. Measuring the rent by the price advertised to the market by leasing agents is not uncommon, as several studies used this proxy (Eichholtz et al., 2010; Fuerst & McAllister, 2009; 2011a; 2011b; 2011c; Newell et al., 2014). The problem, that asking rent presents according to Gabe and Rehm, is twofold; valuation bias and dependency on other variables associated with asset value.

Additionally, McDonald (2002) stated in a survey of econometric models of office markets, that asking rent is least reliable as a proxy for rent prices.

In this context, a study that seems to evade the aforestated endogeneity problems is the work of Chegut et al. (2013). By controlling for micro-locational differences and using transactional data rather than appraisals or asking rents, Chegut et al. find significant rental and sales premia for BREEAM certified office buildings in the UK, of 19.7% and 14.7% respectively. They also state that investor characteristics can be of modifying impact and suggest future research to account for this. Clearly, this study may be subject to yet another limitation, i.e. a relatively small sample size.

2.2.2 *Benefits for the tenant and the owner*

Further analyzing the findings in the US literature leads to valuable insight. The findings with respect to the price premia for the Energy Star and LEED labels in the US sector of office buildings using hedonic models (Fuerst & McAllister, 2009; 2011a; 2011b; Eichholtz, Kok, & Quigley, 2010; 2013, Pivot & Fisher, 2010; Das & Wiley, 2014; Jaffee, Stanton & Wallace, 2019), are overall consistent with the positive findings aforementioned. However, the utilization of identical sustainability proxies, LEED and Energy Star, provides the possibility to synthesize the results of different studies. The premia in sales value range from 11-35% for LEED and 9-31% for Energy Star, where the premiums paid by the tenant vary from 3-6% for LEED and 3-7% for Energy Star. Put in other words, the relative observed premia in sales value are substantially larger than the premiums paid by the tenants. This may indicate that owners not only value the benefit of green buildings through higher rental incomes but assign much more value to future determinants. That is, owners may anticipate high future value from being green through lower holding costs (due to lower vacancy rates and higher tenant retention) and reduced risk premia, as mentioned by Fuerst & McAllister (2009). Therefore, we can posit that green buildings are relatively more valuable for owners than tenants, based on the logic that future determinants weigh more heavily for owners.

2.2.3 *Evolving regulations and dynamic macro-economic conditions*

Fuerst and McAllister (2009) express their concerns on the tendency of assessing short time frames in the existing literature and emphasize the importance of examining the development of differences in pricing effects over time. Aligned with their results, Reichard et al. (2012) find that the premium paid by the tenant appears to be non-stationary, which is partially explained by the global financial crisis. The authors stress the importance of taking the development of pricing differentials into consideration. Especially since the assessment methods of certification systems may develop over time and office supply could be affected by changes in future regulations. Furthermore, Eicholtz et al. (2013) find that the premium for Energy Star certified office properties annually decreases with 0.4% from the date of issuance. They devote this phenomenon to the so-called label vintage effect, in which the development in labeling requirements may play a substantial role. Additionally, they stress the potential presence of unobserved heterogeneity that may be explained by the tendency of green offices being younger, larger and more accessible relative to public transport.

Furthermore, aligned with Fuerst and McAllister (2009), Reichard et al. (2012), Kok and Jennen (2012), and Eicholtz et al. (2013) also address the need of tracking the effect of interest through time. Namely, they speculate that the standards for Dutch certification systems of office buildings may tighten in the future and that prospective regulations targeted at urban transport may affect the future outlook and importance of green mobility. Besides evolving regulations, they find that changing macro-economic conditions can also be of a modifying effect. Emblematic for these concerns is the regulation that was introduced in 2016 by the Dutch government just after Kok and Jennen published their results. The regulation forces all functioning offices to obtain an energy label of C or higher by 2023.

2.2.4 *Existing literature in the Dutch office market*

In contrast with the US academia, evidence on the evaluation of sustainable offices in the Netherlands is scant, as partially explained earlier by the absence of a centralized database like CoStar. Combined with the slow diffusion of heterogeneous certification systems in the Netherlands the literature has thus far been hindered. Kok and Jennen (2012) are the first to assess the price effects of EPCs for office buildings in the Netherlands. They overcome the lack of a centralized database by combining the data of proprietary transactions from several prominent Dutch real estate agencies. They create a unique dataset of 1072 rental transactions by merging the transactional data with information on the energy characteristics (i.e. EPCs, energy performance index, and the energy consumption) of office buildings as presented by RVO[5]. As shown in table 2.1 and 2.2, the divergent approach of the explanatory variable affirms the complexity of quantifying the rather broad definition of 'sustainability'.

[5] Rijkdienst voor Ondernemend Nederland (RVO) is a Dutch government agency that operates under the auspices of the Ministry of Economic Affairs and Climate Policy.

Nevertheless, Kok and Jennen examine merely two factors that they argue as most important in terms of sustainability: energy efficiency and accessibility with regards to public transport, amenities, and strikingly also highways. As shown in table 2.1, transport is also assessed in the more extensive sustainability certification schemes. However, these certification schemes do deliberately not include the distance to the nearest highway ramps. In contrast to Kok and Jennen, LEED and BREEAM even discourage the use of personal cars by positively appraising office sites that are stimulating green mobility (e.g. through benchmarking parking lots). Nevertheless, the authors find that buildings designated as inefficient (with energy labels D or lower) command 6.5 percent lower rental prices relative to energy-efficient buildings. Corroborating with several existing studies (Chegut et al. 2013; Eichholtz et al., 2013; Fuerst & McAllister, 2011b) they state that accessibility pays as well, with exception to distance to highway ramps.

Furthermore, the Dutch real estate agency DTZ Zadelhoff (2011), states that EPC labels are positively correlated with the appraisal values of 150 Dutch office buildings. However, by using an appraisal-based approach, the study may be sensitive to valuation bias as argued by Bonde and Song (2013). To account for this matter, a similar study by the consultancy Troostwijk Real Estate (2011), examines green premiums using transactional data for both rents and capital values. They compare the rents and prices of green labels (A, B and C) with non-green labels (D, E, F and G) and document a premium for energy-efficient office buildings. The observed premia of both studies show substantial differences. Kok and Jennen (2012) comment on these studies by addressing their shortcomings. Namely, the studies both fail to include crucial factors of office buildings, such as location and the construction year. This may lead to biased results since energy-efficient buildings tend to be younger, which affects their marketability.

An additional insight from the Dutch office market regards the spatial stationarity since it is has been argued that the willingness to pay for green offices is dependent on the region in which the building is located. As such, Heineke (2009) only finds significant results for the effect of the energy-index on the rental price within prime locations in the Randstad area. Further proof comes from DTZ Zadelhoff (2011), who find that the coefficient for offices outside the Randstad area is substantially lower. They argue that within more urban prime locations, energy efficiency weighs more heavily in terms of investment criteria.

2.3 Conclusion Literature Review

In conclusion, the existing literature assesses mainly pre-crisis periods. Since there has been a growing recognition of the global challenges last decade, the diffusion of initiatives such as sustainability certification systems has been accelerated post-crisis. Therefore, the observed premia pre-crisis may have been altered. Moreover, most studies asses a rather short time period, limiting the transferability of results. Also, most literature is found in the US, as explained by the comprehensive and centralized US database, CoStar. Furthermore, international literature predominately shows that office buildings labeled as green achieve higher rents and sales values. Nevertheless, the observed premia range substantially, which becomes particularly illustrative in the US since the use of identical sustainability proxies within the same market aids the comparability. This range in findings emphasizes the importance of accounting for unobserved heterogeneity. As discussed in the literature review, omitting controls for building, locational, and investor characteristics are the most prevalent reasons for endogeneity issues, which may explain the different results. Another observation from the US literature is the different magnitude of relative premia for sales and rental transactions, which may indicate that being green is more valuable for the owner than the tenant.

The European and Dutch literature is relatively scant and focusses primarily on rent or appraisal value, while Bonde and Song (2013) argue that transaction prices would provide more robust results. Moreover, several authors emphasize the importance of accounting for pricing differentials over time due to stricter environmental regulations. For the Dutch office market, this becomes particularly important since the empirical evidence on energy efficiency descends from before the introduction of the 2023 label C requirement. Besides, EPCs only became mandatory in the Netherlands in 2015. Therefore, the existing Dutch evidence might suffer from sample selection issues, since only energy-efficient houses would request a label or EPI before this moment. Next to energy efficiency, several studies present accessibility as the second most crucial element in terms of sustainability. Also, the region in which Dutch offices are located is argued to play a role in the green premium matter (Heineke, 2009; DTZ Zadelhoff, 2011). Lastly, the literature seems to be unanimous about the approach to valuation of office buildings, i.e. the hedonic pricing method is considered as the most suitable methodology for this issue.

Consecutively, all papers that examine the relationship between sustainability metrics and the value of office buildings and discussed above, are summarized in table 2.3 according to their characteristics, sample, methodology, and findings of the premiums.

Table 2.3 – Overview of the studies discussed in the literature review

Characteristics of study			Sample		Methodology		Identified premiums			
Authors	*Year*	*Segment*	*Period*	*Country*	*Hedonic*	*Other*	*Sustainability Variable*	*Sales Transaction (n)*	*Rental Transaction (n)*	*Accessibility relative to train stations (n)*
Bonde & Song	2013	Offices	2003-2010	SE	x		EPC	0 (n/a)**		
Chegut, Eichholtz & Kok	2013	Offices	2000-2009	UK	x		BREEAM	14.7% (64)	19.7% (68)	+ (64)
Das & Wiley	2014	Offices	2004-2011	US	x		LEED Energy Star	10.6% (209) 16.4% (354)		
Eichholtz, Kok, & Quigley	2010	Offices	2004-2007	US	x		LEED Energy Star	11.3% (694) 19.1% (694)	5.2% (209)** 3.3% (774)**	
Eichholtz, Kok, & Quigley	2013	Offices	2007-2009	US	x		LEED Energy Star	11.1% (102) 13% (293)	6% (209) 6.5% (774)	+ (5,083)
Fuerst & McAllister	2009	Offices	1999-2008	US	x	Logistic	LEED Energy Star	35% (127) 31% (662)	6% (210)** 6% (990)**	
Fuerst & McAllister	2011a	Offices	1999-2008	US	x		LEED Energy Star	25% (127) 26% (559)	4-5% (197)** 4-5% (834)**	
Fuerst & McAllister	2011b	Offices	1999-2009	US	x		LEED Energy Star	25% (87) 18% (876)	4-5% (286)** 3-4% (1846)**	+ (11,008)
Fuerst & McAllister	2011c	Commercial	na	UK	x		EPC BREEAM	ns (692)** ns (24)**	ns (692)** ns (24)**	
Gabe & Rehm	2014	Offices	2009-2011	AU	x		NABERS		ns (673)	
Jaffee, Stanton & Wallace	2019	Offices	2001-2010	US	x	Asset pricing	Energy Star	13.5% (141)		
Kok & Jennen	2012	Offices	2005-2010	NL	x		EPC		6.5% (1072)	+ (1,057)
Miller, Spivey & Florance	2008	Offices (only class A)	2003-2007	US	x		LEED Energy Star	10% (248) 5.8% (643)		
Nappi-Choulet & Décamps	2013	Commercial	2010	FR	x		EPC	+ (558)**		
Newell, MacFarlane & Walker	2014	Offices	2011	AU	x		NABERS Green Star	9.4% (206)** 11.8% (23)**	6.7% (206)** 6.6% (23)**	
Pivo, Fisher	2010	Offices	1999-2008	US	x		Energy Star	8.5% (na)	5.2% (na)	
Reichard, Fuerst, Rottke & Zietz	2012	Commercial	2006-2008	US		FE, DID	LEED Energy Star		2.9% (337) 2.5% (1584)	
Wiley, Benefield & Johnson	2010	Offices (only class A)	na	US	x		LEED Energy Star	1255 €/m² (na) 290 €/m² (na)	15-17% (na) 7-9% (na)	

*Note: *The sample sizes only include the labelled buildings only; **Dependent variables are based upon appraisals or asking rents*

3 CONCEPTUAL FRAMEWORK

In this section, the synthesis of the existing studies will be translated into the testable hypotheses that are required to critically reflect upon the previous knowledge and elements drawn from the literature review.

Overall, the authors predominantly find positive price premiums for sustainable certification systems. The range in observed premia can be explained by the authors utilizing different variables or definitions to model sustainability. In the debate on which factors depict the true effects of sustainability, it has been argued that energy efficiency is the most important indicator (Kok & Jennen, 2012). With the aim to clarify the green premia for Dutch office buildings, and using transactional data while combining it with the corresponding EPCs and EPIs, the following hypotheses 1 and 2 are presented for both rental and sales transactions respectively:

H1(a): a high Energy Performance Certification rating (label A, B and C) is positively correlated with the rental transaction price of Dutch office buildings

H1(b): a low Energy Performance Index has a positive effect on the rental transaction price of Dutch office buildings

H2(a): a high Energy Performance Certification rating (labels A, B and C) is positively correlated with the sales transaction price of Dutch office buildings

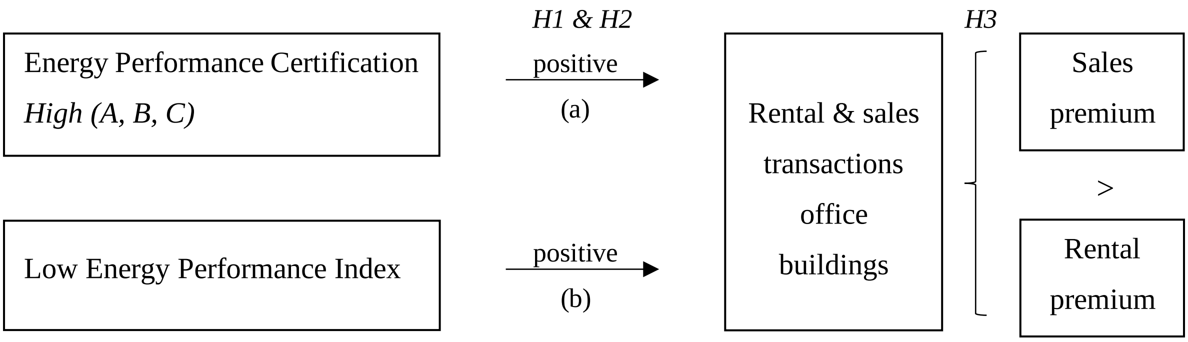
H2(b): a low Energy Performance Index has a positive effect on the sales transaction price of Dutch office buildings

Further, there is a general observation as to the different magnitude of the effects between the transaction types, which becomes particularly illustrative in the US office market (Fuerst & McAllister, 2009; 2011a; 2011b; Eichholtz, Kok, & Quigley, 2010; 2013, Pivot & Fisher, 2010; Das & Wiley, 2014; Jaffee, Stanton & Wallace, 2019). The observed premia in the US indicate that owners exhibit lower return requirements than tenants. That is, the observed green premia tend to be relatively higher for sales transactions than for rental transactions. Therefore, the following hypothesis is introduced:

H3: The magnitude of the relation between energy efficiency and the value of Dutch office buildings is larger for sales transactions than for rental transactions

It has to be noted that the third hypothesis is dependent on previous hypotheses, so it can only be tested if significant results are found in hypotheses 1 and 2.

Figure 3.1 – Visualization of the hypothesized effects of H1, H2 and H3



In continuation, Kok and Jennen (2012) and Reichard et al. (2012) emphasize the importance of controlling for pricing differentials over time. They found that premiums for energy efficiency may alter due to changing macro-economic conditions and regulations that tend to evolve. Their recommendations are supported by Eichholtz et al. (2013), who also address the concern of prospective stricter labeling standards and tighter regulatory frameworks. In the Netherlands such regulations are already set in place, pushing all functioning office buildings towards an EPC of C or higher by 2023. This, combined with the progressively increasing awareness for sustainability in society, leads to the following hypothesis:

H4: The relation between energy efficiency and the transaction price of Dutch office buildings is non-stationary

Additionally, this paper also breaks new ground. Where most studies restrict their ability to make generalizations by only looking at one or a few metropolitan areas, this paper examines the effects of energy efficiency in the office market on a national scale. Although Kok and Jennen (2012) also used a dataset on a national scale for the Dutch office market, this paper is the first to explore Dutch energy efficiency nationwide using transactional data for both sales and rental values. Moreover, Heineke (2009) and DTZ Zadelhoff (2011) argued that the region may be of a modifying effect, carefully hinting that the green premium in more urbanized regions as the Randstad may be stronger. This paper delves deeper into this matter and, to the best of our knowledge, pioneers in the study of green premia for office buildings by including the degree of urbanization in the analysis. Since Heineke (2009) and DTZ Zadelhoff (2011) stated that the offices within the Randstad achieved higher premiums than outside this highly urbanized region, one may postulate that the green premium may be influenced by the urban form. This is supported by widely supported beliefs that spatial clustering positively influences social sustainability (Dempsey, Brown, & Bramley, 2012). Using a national dataset allows testing for the modifying effect of Dutch urbanization, providing useful insights to developers and investors who are operating on a national scale. To examine the effect of the level of urban density, the following hypothesis is provided:

H5: Urban density is of a modifying effect in the relation between energy efficiency and both the rental and sales transaction price of Dutch office buildings

4 METHODOLOGY

This section elaborates on the empirical models that are used to test the relation between energy efficiency and the rental and sales prices. The hedonic model, including the variables, build upon the theoretical framework constructed in previous chapters. Conclusively, potential endogeneity problems that arise when empirically testing this issue are discussed.

4.1 Hedonic pricing model

In the literature, the predominant approach to analyze price premiums with regards to energy efficiency uses the hedonic price model. This paper follows this established methodology and builds the specifications upon the methods used by Eicholtz et al. (2010) and Kok and Jennen (2012). Additionally, it adds the perspective of urban density in the Netherlands on a national scale.

4.1.1 Modeling the green premium

In line with Eicholtz et al. (2010) and Kok and Jennen (2012), the effect of energy efficiency, approximated by EU energy performance certification systems, is analyzed according to the following hedonic specification:

$$\log T_i = \alpha + \beta_1 G_i + \rho_i S_i + \sum_Z^{z=1} \delta_i Z_z + \varphi_i U_i + \tau_i M_i + \varepsilon_i \qquad (1)$$

where the dependent variable is the natural logarithm of the realized rental or sales price per square meter in office building i. Taking the logarithm of the dependent variable aids the comprehensibility of the results since the independent variables can be interpreted as percentages. Additionally, the logarithmic transformation minimizes the relative standard deviation but more importantly, it mitigates the effect of extreme values. For that reason, the regression model becomes more robust as the error term comes closer to normality. The independent variable is specified as G_i, which is a binary variable that takes the value 1 if the building is green (labeled A-C) and zero if the energy performance is labeled as non-green (labeled D-G). In alternate specifications, two different variables are used: both the continuous score of the Energy Index and the specific label category, where label D functions as the reference group. S_i is a vector of structural attributes such as age and the size of the property that can be found in Table A.1[6]. Furthermore, as discussed in the literature review, many authors emphasize the important role of micro-locational factors in determining prices for commercial offices. To control for location the binary variable z_z is included that follows the specification as used in the paper of Kok and Jennen (2012), only controls on a relatively larger and less accurate level. Namely, unlike Kok and Jennen, this variable for ZIP code fixed-effects is unique for each one-digit ZIP code instead of a four-digit ZIP code, resulting in a significant smaller set of locational dummies. Moreover, it is argued that spatial clustering results in agglomeration effects, which are related to many urban attraction factors (Giuliano, Kang & Yuan, 2019). Therefore, in order to limit micro-locational effects that are not included in the one-digit postal fixed effects and thus may be reflected in the prices, a set of three binary variables u_i is included that controls for the degree of urban density. The dummies account for whether the six-digit postal area is considered highly urban, moderately urban or rural. This alternative approach to control for micro-locational effects allows to substantially reduce the number of fixed effects needed to obtain an unbiased estimate of the green premium. Additionally, several authors (Reichardt et al, 2012; Kok & Jennen, 2012; Eicholtz et al., 2013) address the concern of controlling for changing macro conditions and evolving regulations over time. For that reason, a set of binary variables m_i is included to control for the macro effects of each of the five years during the sample period. The dummies take the value 1 if the sale took place in that specific year, using 2015 as the reference year.

4.1.2 Modeling the effect of policy on the green premium

Subsequently, the previous model is expanded by including an interaction variable to examine whether the effect is stationary over time. The interaction variable allows obtaining the effect of the new policy that was announced in October 2016. By distinguishing between the period's ex-ante and ex-post the announcement, it becomes possible to examine in what way the market anticipates the label C requirement that will come into effect in 2023. The modified specification is defined as follows:

$$\log T_i = \alpha + \beta_1 G_i + \gamma_i G_i * Afterpolicy + \rho_i S_i + \sum_{Z}^{z=1} \delta_i Z_z + \varphi_i U_i + \tau_i M_i + \varepsilon_i \qquad (2)$$

[6] Appendix A, table A.1 shows all variables that are required to perform the most ideal hedonic price analysis for the purpose of this paper.

where *Afterpolicy*$_i$ is a dummy variable taking value 1 if the transaction took place after the announcement in October 2016. The coefficient β_1 depicts the effect before the announcement was made and γ_i reveals the effect of being green after it was publicly known that offices should meet the label C requirement by 2023.

4.1.3 Modeling the effects of urban density

Similarly, the first model is used and expanded with interaction variables. For this alternate specification, the dummies for the degree of urbanization interact with the coefficient that represents the green premium. This alternate model allows to examine whether the green premium differs with the level of urbanization and is specified as follows:

$$\log T_i = \alpha + \rho G_i + \gamma_i G_i * U_i + \beta_i S_i + \sum_{Z}^{z=1} \delta_i Z_z + \varphi_i U_i + \tau_i M_i + \varepsilon_i \quad (3)$$

where the variables U_i is the set of dummy variables for moderately urban and rural areas as discussed previously, using high urbanized areas as the reference group.

4.2 Identification Issues

To find the green premium in an ideal world, one would like to observe the prices of two perfectly identical office buildings over time with the only difference being the energy performance or even randomly assign energy performance to different buildings. Unfortunately, such scenarios remain fictional in reality. For that reason, the quality of this research relies on the model specifications and the reliability of the data. This section briefly discusses the potential modeling issues and highlights potential issues arising from the data that is used.

4.2.1 Potential modeling issues

The literature review clearly outlines the necessity of controlling for unobserved heterogeneity when analyzing the price effects of green buildings. The factors that are considered important when examining the willingness to pay for green offices are listed in the variable overview in Table A.3[7]. The variables are categorized using the approach of Weterings et al. (2009), who

[7] Appendix A, table A.3 shows all variables that are required to perform that are ideally included in a hedonic price analysis for the purpose of this paper.

distinguish between four categories that they found important when valuing the rental price of office buildings: investment attributes, structural attributes, locational attributes, and macro effects.

Unfortunately, for this research, we were unable to obtain data on investment characteristics. Chegut et al. (2013) argue that price effects for green buildings differ depending on the distinct investment and tenancy attributes. Put in different words, investment characteristics may be of a modifying effect. For that reason, Chegut et al. (2013) stress the importance to incorporate these factors in the hedonic price analysis. We are conscious that the omittance of these variables may cause limitations to the model.

4.2.2 Potential data issues

In this paper, random errors may partially arise from the data collection process of the datacentre Brainbay. Brainbay collects its transactional data for commercial real estate from realtors that manually submit transactional data to the database. Realtors are not incentivized for accuracy. This may cause potential negligent behavior while entering the data. For that reason, the data will be manually checked and dropped if found deficient or irrational. The descriptive statistics from the studies of Kok and Jennen (2012), and Nappi-Choulet and Décamps (2013) are used to determine the minimum and maximum boundaries for the data in this paper. Next, the observations that fall outside these bandwidths are checked for accuracy by comparing the data with various publically available sources (e.g. Funda in Business). Moreover, the report of NVM Business (2018) and Dynamis[8] (2019) are used to assess the economic rationale of the transaction prices per municipality. This is a rather time-consuming process, yet crucial to guarantee the reliability of the data.

The preceding concerns constitute challenges for the hedonic analyses and therefore ought to be kept in mind throughout this paper. Given this context, lower levels of significance[9] are anticipated that will be interpreted as potential effects that require further study.

[8] Dynamis is an overarching organization of 13 real estate agents that they facilitate with research on, among others, the office market.

[9] Results are treated as evidence below 5% significance levels and treated as potential effects if only significant at a 10% level of significance.

5 DATA

As discussed in chapter 2.1.3, obtaining transactional data of commercial real estate is notoriously difficult in the Netherlands (Kok & Jennen, 2012). Lacking consistent data like for instance those provided by CoStar, we combine the proprietary transactional data of offices from Brainbay with publicly available data on energy characteristics from RVO. Conclusively, data from CBS[10] on the urban density is added to the matched dataset. To impede potential misunderstandings on methodological choices that are made due to data constraints, the data is briefly summarized and described.

5.1 Sample Matching

5.1.1 Brainbay – Transactional data

Brainbay is a subsidiary of Nederlandse Vereniging van Makelaars en Taxateurs (NVM) and the largest datacenter in the Netherlands with regards to real estate. Brainbay provides, *inter alia*, panel data registered by realtors on both rental and sales transactions prices of commercial real estate for research purposes. The EPCs only became mandatory for commercial real estate in 2015. To preclude potential sample selection bias, as only more energy-efficient buildings would have requested an energy label before this moment, this paper focusses on transactions from 2015 onwards. More specifically, the dataset used in this analysis contains the transactions for Dutch office buildings nationwide registered at Brainbay from 2015 to 2019. The data is object-specific and comprises important characteristics of the office buildings and the corresponding transactions. All observations are denoted by a postal code, house number, and suffix[11].

5.1.2 Rijksdienst voor Ondernemend Nederland – Energy efficiency

The RVO is a government agency that operates under the auspices of the Ministry of Economic Affairs and Climate Policy and supports entrepreneurs, NGOs, knowledge institutions and organizations[12]. The RVO provides an open database for commercial real estate, containing

[10] Central Agency for Statistics (CBS) is a Dutch governmental organization that gathers statistical information about the Netherlands.

[11] Suffix is an addition to a house number. For example: if an apartment is located on the postal code 1020AB, with house number 70 on the second floor, than the suffix can be denoted by II, 2, B etc.

[12] This information was sourced from the RVO website: https://www.rvo.nl

over 40,000 office buildings and their corresponding EPC ratings and EPI scores. Every year the database is renewed, meaning that only data from the year 2019 is available. However, the date of issuance is included and given the 10-year validity, the dataset includes EPC ratings and EPI scores from up to 2009. Again, all observations are denoted by a postal code, house number, and suffix.

5.1.3 StatLine – Urban density

StatLine is the database of the CBS and provides data on the economy and the Dutch society. The datacentre allows users to compile, adjust and download data tailored to your own needs. For this paper, the urban density scores are extracted that are denoted by 10-digit neighborhood codes. Unfortunately, StatLine doesn't allow to add corresponding postal codes, which is required to match the density scores with the data from Brainbay and RVO. Therefore, the urban density data is matched with another dataset from CBS that contains all neighborhoods in the Netherlands and the corresponding postal codes. The urban density is measured by the number of addresses per square kilometer and ranked from 1 to 5. As shown in Table 5.1, in this paper the scores are categorized into three groups following the approach of the European Commission (2018).

Table 5.1 – Urban density

	Highly urban	Moderately urban		Rural	
CBS score	1	2	3	4	5
Addresses per km^2	>2500	2500-1500	1500-1000	1000-500	<500

5.1.4 Matching procedure and sample construction

The two datasets are checked separately for duplicate values in the data, and if required corrected for. Next, the two datasets are matched according to the postal code, house number, and suffix. Where the numerification of postal codes and housing numbers are normalized to four digits, two letters and a number respectively, the suffixes of offices distinct widely (e.g. A, II, sous, unit102). The latter results in matching issues. This becomes clear by the significant difference in unique suffixes used in both datasets, i.e. 470 versus 811 unique suffixes for the RVO and Brainbay dataset respectively. Moreover, within the dataset of RVO, only 4% of the office buildings have more than one office registered at the same address while having different energy labels for the multiple suffixes that belong to that address. This percentage seems immaterial. However, if not randomly distributed, ignoring the suffix while matching the data could create bias. Therefore, the different notations of suffixes (e.g. 2 and II) included in both samples are harmonized manually to improve the matching results. Afterward, the sources are matched according to an identification code (ID). This unique code is created by consolidating the postal code, house number, and the suffix[13].

This paper is primarily focused on the price premia of energy efficiency on both transactional sales and rental prices. This requires corrections of the matched sample. Firstly, the data from RVO only contains the most recent labels and EPI scores of office buildings as registered on 30/06/2019, meaning that transactions not necessarily correspond to the assigned energy characteristics. For example, if an office building with label D is sold on 01/01/2016 and followed by investments in energy efficiency, the office building may be matched to a higher label that is obtained in the consecutive period upon the transaction. Transactions that took place before the matched registration date of the RVO data will be dropped accordingly. Besides, the data will be manually checked and dropped if found deficient or irrational. Moreover, the continuous variables are checked for kurtosis and skewness and if required winsorization is applied. These modifications result in the 'corrected matched sample'. Lastly, the urban density scores are matched on six-digit postal codes. The number of observations for both sales and rental transactions is shown in Table 5.2.

Table 5.2 – Number of observations

	Rental		Sales	
	N	*% of Brainbay*	*N*	*% of Brainbay*
Sample Brainbay	14,225		3,940	
Matched sample	5,484	39%	1,773	45%
Corrected matched sample	2,497	18%	1,127	32%

Additionally, Table 5.3 shows the label distribution of RVO and the corrected matched samples. The number of observations that exhibit labels A+, A++, A+++, A++++ are limited and not suited for representative analysis. Therefore, these labels are transformed into the A-label. In all three samples, the majority of the office buildings are labeled as efficient, with a total of 70%, 67%, and 56% respectively. Overall, the label distribution of the corrected matched samples is consistent with the RVO data, with exception to the slight differences in the sales sample where relatively more offices exhibit label G.

[13] For illustration, an office building with postal code 1020, house number 70 and suffix B, is assigned to the following identification code (ID): 1020AB70B

Table 5.3 - EPC distribution of the corrected matched samples

	RVO		Rental		Sales	
	N	*%*	*N*	*%*	*N*	*%*
Label A	16,392	40%	884	35%	312	28%
Label B	5,211	13%	325	13%	137	12%
Label C	7,090	17%	474	19%	187	17%
Label D	3,771	9%	240	10%	130	12%
Label E	2,434	6%	175	7%	84	7%
Label F	1,752	4%	101	4%	60	5%
Label G	4,816	12%	298	12%	217	19%
Total	41,466		2,497		1,127	

5.2 Descriptive Statistics

Similar to the approach of Kok and Jennen (2012) and Chegut et al. (2014), this paper summarizes and describes the data according to a separate panel for energy-efficient buildings (label A, B or C) and energy inefficient buildings (label D, E, F or G). An overview of the summary statistics can be found in Table 5.4.

As this study is mainly interested in the willingness of the tenant or investor to pay for energy efficiency, the simple comparison of the average price per square meter of both panels could be an early indication that sustainability is capitalized in the Dutch office property market. The parameter of interest for green offices is on average €129 and €1133 for rental and sales respectively. That compares to €131 and €1172 respectively for non-green buildings. The same holds ante-winsorization. This simple comparison indicates that lower energy efficiency implies a higher transaction price. The latter strikes with the postulation that is constructed on the findings of the literature review. However, it has to be noted that this comparison does not control for other crucial differentials between the two panels, such as the construction year and spatial elements. For illustration, green buildings in both samples are on average constructed 30 years ago, whereas the average non-green office is twice as old, aligned with the age statistics of Kok & Jennen (2012). Simultaneously, this confirms the tendency of green offices being younger as argued by Eicholtz et al. (2013).

Moreover, the summary statistics show a rather small amount of observations for parking facilities. Ideally, one would control for this factor. However, for less than 10 percent of the total sample, realtors stated whether the transaction included parking facilities. For this reason, the variable parking spots will be omitted in further analysis.

Table 5.4 - Summary statistics of both rental and sales transactions categorized into two panels: energy efficient (A) and energy inefficient (B)

Rental	N	Mean	Median	St. Dev.	Minimum	Maximum
Panel A: Properties with Label A-C						
Transaction Price (€/sqm)	1683	129.22	117	62.85	12	600
Transaction Price* (€/sqm)	1683	128.61	117	59.31	24	360
Size of transaction (sqm)	1683	364.66	190	683.13	10	12622
Size of transaction* (sqm)	1683	336.78	190	461.85	20	2690
Energy Efficiency Index	1683	1.03	1.05	0.19	0.18	1.3
Age (Years)	1683	28.78	20	28.48	1	319
Registration age (Years)	1683	2.50	2	1.77	0	10
Parking spots	175	12.82	5	22.21	0	150
Existing build	1658					
New build	25					
Panel B: Properties with Label D-G						
Transaction Price (€/sqm)	814	132.44	119	69.48	10	600
Transaction Price* (€/sqm)	814	131.06	119	62.63	24	360
Size of transaction (sqm)	814	282.48	160	413.56	10	4450
Size of transaction* (sqm)	814	227.81	160	375.43	20	2690
Energy Efficiency Index	814	1.79	1.6	0.5	1.31	4.66
Age (Years)	814	63.52	50	46.95	6	469
Registration age (Years)	814	2.88	3	1.77	0	10
Parking spots	67	5.43	3	5.85	0	28
Existing build	814					
New build	0					
Sales	N	Mean	Median	St. Dev.	Minimum	Maximum
Panel A: Properties with Label A-C						
Transaction Price (€/sqm)	636	1141.65	983.23	746.33	150	6639.78
Transaction Price* (€/sqm)	636	1132.76	983.23	693.42	205.85	4428.2
Size of transaction (sqm)	636	745.38	385	1037.721	30	13830
Size of transaction* (sqm)	636	731.05	385	910.88	52	5494
Energy Efficiency Index	636	1.04	1.06	0.18	0.13	1.3
Age (Years)	636	28.56	20	26.38	1	251
Registration age (Years)	636	2.28	2	1.54	0	10
Parking spots	78	18.72	12	21.61	1	108
Existing build	631					
New build	5					
Panel B: Properties with Label D-G						
Transaction Price (€/sqm)	491	1184.45	913.04	889.03	149.78	6867.65
Transaction Price* (€/sqm)	491	1172.65	913.04	830.05	205.85	4438.2
Size of transaction (sqm)	491	874.9	384	3312.55	10	70000
Size of transaction* (sqm)	491	720.75	384	962.56	52	5494
Energy Efficiency Index	491	1.83	1.68	0.48	1.31	3.95
Age (Years)	491	63.92	53	39.43	7	394
Registration age (Years)	491	2.69	3	1.59	0	10
Parking spots	59	13.95	8	18.46	0	87
Existing build	491					
New build	0					

*Note: *Winsorized at fraction 0.01*

Table 5.5 shows the distribution of the transactions over the sample period. The announcement in 2012 that restricts offices to a label C minimum as of 2023, may have a serious impact on the dynamics within the office market (Reichardt et al, 2012; Kok & Jennen, 2012). Following the reasoning of these authors, the new regulation may seep through to the Dutch office supply, causing a shift from non-green to green office buildings over time.

Aligned with these expectations, the sales sample clearly depicts a shift from non-green to green office properties over the years. Where the sales sample is equally spread in 2015, the proportion of green offices increases to 66% in 2019.

However, this tendency does not seem to hold for rental transactions. At first glance, the proportions of green to non-green offices appear to stay rather constant over time. This may be explained by the fact that some owners are unable to meet the future label C requirement. That is, for owners of 'energy hogs' the relatively low rent levels do not compensate for the relatively high investment costs. For this reason, they may refrain from investments in energy efficiency improvements. This is also confirmed by the disproportional amount of transactions with label G, as shown in Table 4.2. The EIB[14] (2016) estimates that 0.9% of the total Dutch office supply will vanish as of this matter. Put differently, the label C requirement results in the withdrawal of 720,000 square meters of leasable office floor by 2023. This loss of office stock mainly involves offices labeled with the worst energy performance (label G) that take account for 70% of buildings that will withdraw from the office market. The other 30% is spread over the office buildings with energy labels D-F.

Table 5.5 - Distribution transactions over the sample period

	Rental		Sales	
Transaction year	Green	Non-green	Green	Non-green
= 2015	68%	32%	50%	50%
= 2016	65%	35%	53%	47%
= 2017	68%	32%	58%	42%
= 2018	72%	28%	61%	39%
= 2019	68%	32%	66%	34%

In conclusion, given the 2023 label C requirement investors may be reluctant for investing energy-inefficient office properties due to their long-term investment horizon, causing a decreasing trend of sales transactions. In contrast, tenants that enter into leasing contracts of energy inefficient office space may be less affected with long-term restrictions, delaying their shift to energy-efficient buildings until the new policy comes into force.

Additionally, different types of relevant charts and figures are constructed to aid a deeper understanding of the statistics, which can be found in Appendix A[15]. Pearson's

[14] The Economic Built Institution (EBI) is a research agency focused applied economic analysis concerning the Dutch construction sector and the built environment

[15] Appendix A provides extensive descriptive statistics, i.e. charts, figures and Pearson's correlation matrices.

correlation matrices include the variables used for the analysis and can be found in Appendix A2 and A3. Both tables indicate a relatively weak positive relationship between energy efficiency and the transaction price. Noteworthy is the relatively high correlation between age and the binary variables for urbanization, which is not surprising given that relatively older buildings are often located in areas with high levels of urban density (e.g. city-centers). The correlation between the EPI and the transaction price is portrayed in a scatterplot, as can be seen in Figure A.1. The scatterplots give a clear visualization of the positive relation between the energy performance and the realized prices in the Dutch office market. Note that this correlation is too simplistic to infer causality. However, the scatterplots do graphically reveal extreme values. To limit the effects of potential spurious outliers, the transaction prices are winsorized at fraction 0.1. Figure A.2 displays the same scatterplots, only then after the winsorization of the dependent variable. Lastly, Figure A.5 shows the development of the average rental prices for the transactions used in the empirical analyses of this paper for the years 2015-2018, along with the average prices extracted from the yearly reports of both NVM Business (2019) and Dynamis (2019). The similar trendlines affirm the representativeness of the data used in this paper. Lastly, the logarithmic functions of the prices of the Dutch rental and sales transactions used in this analysis are reflected in a heat map, as can be seen in Figure A.6 and A.7 respectively. Unsurprisingly, the heatmap of the average transaction price per municipality show similarities to the heatmap distribution of the Dutch urban density in Figure A.8. This affirms the beliefs that transactions in more urbanized areas obtain higher prices.

6 RESULTS AND DISCUSSION

In this section, the results of the different models are presented. First, the relationship between energy efficiency and the transaction price of office properties for the rental sample will be established, as well as for the sample for sales transactions. After the energy efficiency-transaction price model is established, the modifying effect of the future policy will be examined by adding interaction terms. Similarly, to test whether the level of urban density is a moderator in the green premium matter, interaction terms for the urbanization will be added to the base model. All in all, the different models indicate a positive, although not always significant, a price premium for energy-efficient office buildings. Aligned with the expectations, but striking with the earlier simple comparison made in 5.2 that was made upon the statistics from Table 5.4, which suggested the opposite. This stresses the importance to control for certain factors to limit bias in estimators due to unobserved heterogeneity. Finally, several alternations will be made to the models and the variables to check the robustness of the results.

6.1 Hedonic pricing model

6.1.1 The green premium paid

The results of model 1 are shown in Table 6.1 and are grossly aligned with the expectations that were built upon the literature review. Hereby do columns 1-3 display the results for the transactional rental sample and columns 4-6 for the transactional sale sample. The dependent variable in all six columns is the logarithmic function of the transaction price. For both samples, the results are shown by three columns where the variable interest is denoted by the dummy variable for offices being green, each of the energy labels, and the energy index respectively.

Columns 1 and 4 thus present the percentage price difference that is paid for a green label (A, B or C) in comparison with non-green offices that are labeled D or lower. The effect is material and substantially significant for the model with the logarithm of the sales price per sqm, and even stronger significant with the dependent variable being the rental price per sqm. The green premia for offices, 7.6% and 7.7% for sales and rental transactions respectively, are similar to the observed EPC sales premium in France (Nappi-Choulet & Décamps, 2013) and the rental premium in the Netherlands (Kok & Jennen, 2012), as stated in Table 2.3.

Table 6.1 - Results of model 1 with the logarithm of both the transactional rental and sales price (€/sqm) as the dependent variables

	Rental Price (ln €/sqm)						Sales Price (ln €/sqm)					
	(1)		(2)		(3)		(4)		(5)		(6)	
Green *(A, B or C)*	0.077***	(0.020)					0.076**	(0.034)				
Label Category[A]												
A			0.023	(0.030)					0.019	(0.051)		
B			0.044	(0.034)					0.064	(0.056)		
C			0.064**	(0.031)					0.078	(0.051)		
E			-0.068**	(0.039)					-0.007	(0.062)		
F			-0.039	(0.048)					-0.180*	(0.070)		
G			-0.049	(0.036)					-0.007	(0.054)		
Energy Index *(inverse ln)*					0.071***	(0.022)					0.048**	(0.036)
Moderately urban[B]	-0.175***	(0.019)	-0.175***	(0.020)	-0.171***	(0.020)	-0.189***	(0.037)	-0.197***	(0.037)	-0.190***	(0.037)
Rural[B]	-0.270***	(0.023)	-0.268***	(0.023)	-0.265***	(0.023)	-0.335***	(0.040)	-0.335***	(0.040)	-0.332***	(0.040)
Size (ln sqm)	-0.089***	(0.008)	-0.089***	(0.008)	-0.089***	(0.008)	-0.300***	(0.014)	-0.301***	(0.014)	-0.300***	(0.014)
Label vintage effect	-0.009*	(0.005)	-0.008	(0.005)	-0.008*	(0.005)	-0.012	(0.011)	-0.012	(0.011)	-0.011	(0.011)
Other controls												
Age	Yes		Yes		Yes		Yes		Yes		Yes	
Postal codes	Yes		Yes		Yes		Yes		Yes		Yes	
Macro effects	Yes		Yes		Yes		Yes		Yes		Yes	
Observations	2,497		2,497		2,497		1,126		1,126		1,126	
R-squared	0.253		0.255		0.252		0.484		0.490		0.483	
Adj. R-squared	0.245		0.245		0.243		0.469		0.474		0.471	

Notes: Due to the high number of binary variables, several coefficients are omitted. Complete results can be found in Appendix B. Standard errors in parentheses. ***, **, *: significant at 10%, 5% and 1% respectively.
[A] Reference group is label D
[B] Reference group are offices in highly urban areas

Columns 2 and 5 depict the effects of each energy label separately and show slightly different results as to columns 1 and 4. This can be explained by the use of the neutral label D as the reference point in column 2 and 5, where the reference in column 1 and 4 is the opposing group (i.e. green versus non-green), with D-G labels being considered non-green. Again, positive price premia for offices labeled as green and negative coefficients for non-green office are observed. For tenants, the coefficients only appear significant for labels C and E, which also show the highest parameters. This may indicate that in terms of sustainability, tenants value the transition to being green the most, after which the effects of energy efficiency gradually abates in size, similar to the findings of Kok and Jennen (2012). Vice versa, tenants seem to put the most weight on the first label (E) towards green deterioration. This may also be indicative of a sorting effect. That is, firms that are driven by CSR purposes may always sort themself in the best buildings labeled with A and B. Offices with labels C, D and E may attract owners and tenants that are not heavily influenced by CSR strategies but do make an actual tradeoff by weighing up the pros and cons of the different labels. Lastly, the worst energy performing buildings (labeled with F and G) may be left with businesses that do not care at all. In continuation, the effects of the transactional sales sample have to be interpreted with greater caution since assessing the label separately leads to substantially lower observations per estimate. Therefore, columns 2 and 5 may potentially suffer from small sample bias. These limitations aside, the signs of the coefficients appear to behave similarly to the rental sample and the expectations.

In columns 3 and 6 the effects of the Energy Index are shown, where the index form functions negatively, i.e. the lower the index, the higher the energy efficiency. To impede potential misinterpretation and aid the comprehensibility of the parameters, the inverse of the logarithmic function is used, meaning that a higher Energy Index equals higher energy efficiency. Columns 3 and 6 show that a 10% increase in the energy efficiency results in a significant green premium of 0.71% and 0.48% respectively. This is grossly aligned with Kok and Jennen (2012), who find that a one-point increase in the Energy Index results in a 5% lower rental price. To illustrate, given an office that scores 2 on the Energy Index, a one-point decrease (or a 100% decrease) leads to 5% higher rental prices according to Kok and Jennen (2012). Similarly, this paper founds that the latter change in energy performance results in green premiums of 7.1% and 4.8% for both rental and sales transactions.

In continuation, the control variables will be discussed for the rental and sales samples simultaneously. Since the variables stay rather constant between the samples in terms of interpretation and significance only columns 1 and 4 of Table B1[16] will be discussed. In line with expectations, the table document significantly negative coefficients for the logarithmic function of the size of the transaction in sqm, which indicate that the larger the transaction size in terms of total sqm the lower the realized price in €/sqm. In contrast, no sufficient evidence is found that supports the label vintage effect for the energy labels as mentioned by Eicholtz et al. (2013). Moreover, the degree of urbanization shows strong and significant evidence that the lower the urban density, the lower the transaction price. With highly urbanized 6-digit postal areas as the point of reference, offices in moderately urban and rural areas realize between 17-20% and 27-34% lower returns respectively. The urban density estimator is likely to be biased due to omitted variables. That is, the coefficients are potentially inflated by micro-locational effects of variables such as mobility or accessibility that are also captured by the level of urbanization on a 6-digit postal level. This is not troublesome in terms of the analysis since the goal of this paper is not to measure the unbiased effects of urban density but rather to provide accurate estimates of the green premium. On the contrary, it may improve the green premium estimates, explained by the following. First, the biased urbanization estimator filters for unwanted variance in the observed price effects due to the inclusion of various locational effects on low micro-level (i.e. 6-digit postal level). Simultaneously, it limits issues of overparameterizing that arise when including large vectors of ZIP code dummies when controlling for postal codes bigger than 1-digit areas. In continuation, the construction period dummies of buildings under 100 years are categorized in groups with a 10-year range, using offices aged between 51-60 as the reference group. The age effects are visualized in Figure B2 and B3[17]. As expected, both figures clearly portray a new build effect that is gradually increasing as the properties become younger. Vice versa, the opposite holds for the building vintage effect, where prices increase gradually as the buildings become older. This may be explained twofold: monumental status and the tendency of older buildings to be located in more urbanized areas (e.g. historic city centers) as discussed by Eichholtz et al. (2013). The controls for 1-digit ZIP codes mostly show significant parameters, using postal areas that start with 1 as the reference group. The reference area covers the region around Amsterdam, which is considered a prime location (NVM, 2018). For the rental sample, all other regions have lower returns in terms of the transaction price. For the sales sample, only the effects for the mid-east

[16] Appendix B, Table B1 shows the complete output of the regression analyses of model 1 with the inclusion of all variables.

[17] Appendix B, Figures B2 and B3 visualize both the new build effect and the vintage effect for the construction age of offices.

and north-east regions of the Netherlands are significantly negative. Lastly, the coefficients for the macro effects are predominantly significant and portray the rising transactional prices over the years.

Besides, the explanatory values (Adj. R-Squared) of the models are relatively low compared to similar studies within the field of residential real estate, where hedonic regression analyses generally explain the residuals for 80 percent (Brounen & Kok, 2011). However, since data of commercial real estate is notoriously difficult to obtain in most countries, the hedonic price models are limited by data constraints resulting in lower explanatory values. For this reason, the explanatory values as displayed in Table 6.1, when put within the appropriate frame of reference, can be considered acceptable. In the literature, within the segment of office buildings, Kok & Jennen (2012) achieve relatively high explanatory values, presumably through the use of more control. Despite the fact that the explanatory powers are informative, one should not solely rely on these statistics when assessing the quality of the regression models. Namely, on one hand, it can be argued that Kok and Jennen are able to explain for more residuals by limiting the omitted variables bias through the inclusion of variables such as investor attributes and more accurate locational dummies. On the other hand, one could argue that their study is overparameterized with a large vector of locational dummies due to the high amount of binary variables required to control for 4-digit ZIP code fixed effects. This becomes especially troublesome given their relatively small dataset on a national scale. Although they present limited statistics that allow examining the overparameterizing issue, one may reason that the alternative approach of controlling for micro-locational effects used in this paper leads to a more parsimonious model. That is, considering the limited observations in this paper, the control for location is on a relatively rougher scale (i.e. one-digit ZIP codes). This accuracy issue is partially solved by adding controls for the level of urban density on a six-digit postal level. In that manner, micro-locational effects are included on a low micro level while sacrificing only three degrees of freedom, explaining the relatively lower R-squared.

Conclusively, the results from the first hedonic pricing model indicate that there is a positive price premium for green offices. Offices that are considered green obtain 7.7% and 7.6% higher transactional rental and sales prices respectively, compared to their non-green anthesis. The estimated results for the Energy Index provide supporting evidence, i.e. a 10% increase in energy efficiency results in a 7.1% rental and a 4.8% sales premium. Although the effects for the separate energy labels are individually less convincing, the robust results across specifications provide strong evidence for hypotheses 1 and 2. Moreover, the results contradict hypothesis 3, as the results indicate the opposite effect.

6.1.2 The effect of policy on the green premium

Ideally, the base model is used to regress the analysis for each year separately before running the second model. Unfortunately, due to the small number of observations, regressing the base-model separately for each year is not suited for representative analysis. Therefore, only model 2 is used to examine whether the coefficients are stationary before and after the announcement of the policy. Following the same reasoning, the second model is only tested for the relatively larger rental sample. The results of the second model can be found in the second column of Table 6.2, where column 1 shows the output of the base model.

Table 6.2 – Results of model 2 with the logarithm of the transactional rental price (€/sqm) as the dependent variable

	Logarithm Rental Price in €/sqm			
VARIABLES	(1)		(2)	
Green *(A, B or C)*	0.077***	(0.020)	0.088**	(0.038)
Green * Afterpolicy			-0.014*	(0.039)
Moderately urban	-0.175***	(0.019)	-0.175***	(0.019)
Rural	-0.270***	(0.023)	-0.270***	(0.023)
Label vintage effect	-0.009*	(0.005)	-0.009*	(0.005)
Size (log sqm)	-0.089***	(0.008)	-0.089***	(0.008)
Macro effects				
year 2016	-0.021	(0.040)	-0.027	(0.040)
year 2017	0.051*	(0.037)	0.043*	(0.045)
year 2018	0.079**	(0.036)	0.063*	(0.044)
year 2019	0.127***	(0.037)	0.102**	(0.045)
Other controls				
Age	Yes			Yes
Urban density	Yes			Yes
Postal codes	Yes			Yes
Observations	2,497		2,497	
R-squared	0.253		0.253	
Adj. R-squared	0.245		0.244	

Notes: Due to the high number of binary variables, several coefficients are omitted. Complete results can be found in Appendix B. Standard errors in parentheses. ***, **, *: significant at 10%, 5% and 1% respectively.
[A] Reference year is 2015

The coefficient of the variable *Green* in the second column depicts the green premium before the announcement of the new restriction on energy labels was made in October 2016. In line with the first model (column 1), the coefficient indicates a significant price premium for sustainable offices. Interestingly, the premium is 1.1% higher before the announcement of the stricter regulations, indicating a negative effect of the policy on the green premium. The latter is weakly supported by the interaction variable *Green * Afterpolicy*, which hints that the willingness to pay for energy efficiency decreases with 1.4% after the announcement date, *ceteris paribus*. This adds up to a price premium of roughly 7.4% for green offices after the announcement.

Besides, when assessing the control variables small change is observed in comparison to model 1, as shown in the first column of Table B2[18]. The coefficients stay significant and constant when adding the interaction variable to the base model. The small change in magnitudes of the parameters is negligible. The same holds for both the R-squared and the adjusted R-squared.

Conclusively, the negative coefficient for the interaction variable in column 4 portrays a lower green premium as of November 2016. Although the exact driver behind this negative effect may be hard to identify, this may hint that the premium that tenants are willing to pay for being green reduces with the knowledge that in the near future green labels will, inter alia, not be an instrument to increase CSR anymore, but rather the new standard. If the latter is not true, then this effect may be explained by less favorable macro-conditions. However, it has to be noted that this effect is only significant at a 10% significance level and it should be interpreted as an interesting future direction for research since the null-hypothesis can't be rejected.

6.1.3 The effects of urban density

The third model that evaluates the price effect of energy efficiency for office buildings, includes the interaction variables between the green labels and the degree of the urban density. This allows examining whether the level of urbanization affects the relationship between energy efficiency and the transactional rent price. Table 6.3 presents the results of model 2 in the second column, and for comparison, the results of the baseline model in the first column. The general effects of the control variables seem to be similar to the baseline models, as can be seen in Table B2. The same is true for the explanatory power of the second model.

The coefficient *Green* in column 2 can be interpreted as the premium tenants pay for energy efficiency within highly urbanized areas. The estimated results reveal that the price premium for green offices is significantly higher within highly urbanized areas. Moreover, the observed premium of 13.1% is remarkably higher in comparison with the baseline model.

[18] Appendix B, Table B2 shows the complete output of the regression analyses of model 2 and 3 with the inclusion of all variables.

Additionally, the interaction variables between the dependent variable and the two binary urbanization variables, both hint that the effects of energy efficiency are less pronounced in less urbanized areas. The interaction variables signify that the green premium decreases with 6.5% for offices within more moderate regions and almost diminishes for offices in rural areas, with a decrease to 12.4%. This means that the effect of urban density is so strong, that the coefficient of being more than doubles in highly urbanized regions. Albeit, the latter may seem extreme, DTZ Zadelhoff (2011) find similar effects for offices located on prime locations within the Randstad region compared to offices outside this highly urbanized region. However, as discussed before, the estimates of urbanization are likely to include other the effects of other omitted micro-locational variables. Therefore, the modifying effects as stated in Table 6.3 may not be solely attributable to the level of density.

Table 6.3 - Results of model 2 with the logarithm of the transactional rental price (€/sqm) as the dependent variable

	Logarithm Rental Price in €/sqm			
VARIABLES	(1)		(2)	
Green *(A, B or C)*	0.077***	(0.020)	0.131***	(0.029)
Green * moderately urban			-0.065*	(0.039)
Green * rural			-0.124***	(0.048)
Moderately urban	-0.175***	(0.019)	-0.130***	(0.032)
Rural	-0.270***	(0.023)	-0.175***	(0.042)
Label vintage effect	-0.009*	(0.005)	0.009*	(0.005)
Size (log sqm)	-0.089***	(0.008)	-0.089***	(0.008)
Other controls				
Age	Yes			Yes
Postal codes	Yes			Yes
Macro effects	Yes			Yes
Observations	2,497		2,497	
R-squared	0.253		0.253	
Adj. R-squared	0.245		0.244	

Notes: Due to the high number of binary variables, several coefficients are omitted. Complete results can be found in Appendix B. Standard errors in parentheses. ***, **, *: significant at 10%, 5% and 1% respectively.
[A] Reference group are offices in highly urban areas

Given the lower level of significance, the interaction variables of urban density are checked for joint significance. The F-statistic, as stated in Figure B1[19], affirms the joint

[19] Appendix B, Figure B3 shows the F-statistic for joint significance testing of the interaction variables *Green * Moderately Urban* and *Green * Rural*

significance at a 5% significance level. In conclusion, the results as documented in Table 6.3 provide strong evidence for hypothesis 5, which may indicate that energy efficiency is a more valuable investment criterion within highly urbanized regions.

6.2 Robustness checks

To check the robustness of the estimated results from section 6.1, this paragraph discusses the several alternations that are made to the model and the variables used. Overall, the results presented in this study have proven to be robust for the additional sensitivity checks.

As discussed in previous sections, alternative proxies have been used to examine the effect of energy efficiency. Table 6.1 (columns 3 and 6) shows that using the Energy Index instead of the categorization of green and non-green EPCs leads to similar results. The latter shows that the results are robust for using a different measure for energy efficiency.

Additionally, as mentioned in section 5.1.4, the data on energy efficiency and transactions are merged according to ID codes that included the suffix. Unsurprisingly, omitting the suffix from the matching process results in substantially higher matching results. As another check for robustness, the regressions of the baseline model 1 were performed with the larger samples. The robustness results in Table C.1[20] document lower coefficients and a lower R-squared. Naturally, faulty matches lead to lower explanatory power. This affirms the expectations that merging according to ID codes that include the suffix leads to more accurate matches. Moreover, all transactions that took place before the date the corresponding energy performance was issued are dropped. However, one could argue that the energy performance of office buildings is stationary. To check whether this is true, the same regressions as shown in Table 6.1 are performed without filtering for the aforementioned criterion. The results in Table C.2 comply with the results found earlier. The decrease in both magnitude and significance indicates that energy performance is non-stationary and non-active labels should be accounted for. Hence, the latter approves the choice to drop all non-active energy labels.

Overall, the control variables used in the hedonic pricing analyses exhibit the expected signs although not all coefficients attain the desired level of significance. To ensure the robustness of the results, the control variables were checked for kurtosis and skewness in section 5.1 prior to the empirical analyses.

Next, several changes are made to the variables of which the approach may potentially evoke discussion. This paper pioneers though the inclusion of urban density, which is measured

[20] Appendix C, Tables C1-C5 show the regression results for all robustness checks that are performed..

on a continuous scale from 1 to 5. As discussed in 5.1.3, the scores of urban density are categorized into three groups (i.e. highly urban, moderately urban and rural) to aid the comprehensibility of the regression output. To check whether the results are robust for this classification, the baseline regression is performed with both the categories and continuous scale as controls for urban density. Table C.3 shows that the results are robust for this alteration and only changes slightly in the rental sample.

Furthermore, a point of discussion could be that the locational controls used in this paper are based on rather large areas and inadequately control for micro-locational effects. For this reason, the same regressions are performed with controls for 2-digit postal codes. The results in Table C.4 show substantial lower premia for green offices when controlling for one-digit higher postal code. Although controlling for urban density within 6-digit postal areas, the observed premia that were found in section 6.1 may potentially be inflated with other micro-locational effects. Nevertheless, to bring nuance to the aforestated, the datasets used in this paper only contains between 1.000 and 3.000 observations nationwide. This means that increasing the controls for ZIP code fixed effects from 1-digit to 2-digit postal areas already results in postal regions with fewer than 2 observations. This may also explain the lower significance in columns 2 and 4 of Table C.4. Although a set of binary variables for 4-digit postal areas would be favored in terms of controlling for micro-locational effects (Kok & Jennen, 2012), 1-digit postal dummies seem the most appropriate given data constraints in this study.

Finally, the future regulation of the Dutch government that makes it mandatory for all Dutch office buildings to meet at least the energy performance requirements of a C label is the first step towards the desired energy-neutral[21] built environment. To realize these long-run goals, the Dutch government already announced follow-up regulations. The future targets that are set for the Dutch office market include a mandatory A-label as of 2030 and complete energy-neutrality in 2050 (EIB, 2016). Given these forthcoming regulations, owners of inefficient offices may be better off by going full monty in terms of investments in energy improvements. This belief is supported by EIB (2016) that estimated the payback periods of energy-efficiency investments as shown in Table 6.3. The general rule for label improvements implies that the smaller the label step, the longer the period of payback.

Currently, owners of non-green buildings are confronted with the choice to invest in energy improvements and meet the prospective 2023 standard or withdraw their assets from

[21] Energy-neutrality equals an Energy Index of zero.

the office market (i.e. demolishment or repurposing) otherwise. The follow-up regulations impose further compilations for the latter investment decision. Namely, Table 6.3 shows that incrementally improving energy-inefficient offices from inefficient to label-C to label-A, results in substantially longer payback periods compared with investments that take a direct and bigger jump towards an A-label. That investments in energy improvements on buildings with higher energy efficiency take longer to recover can be explained by the rather high refurbishment costs and low resulting savings on the energy bill (EIB, 2016).

Table 6.3 - Payback period label improvements

From	Label G	Label F	Label E	Label D	Label C	Label B
To						
Label C	4.5	5	5	6.5		
Label B	4.5	4	6	5.5	6	
Label A	4.5	6	4.5	8.5	9	13.5

Source: EIB (2016)

The payback periods as portrayed in Table 6.3 combined with the outspoken desires of the Dutch government, which encompasses an energy-neutral built environment, may incentivize owners to take a big leap rather than smaller labeling steps. Therefore, it is examined whether owners and investors anticipate the latter and are willing to pay an extra premium for office buildings with an A-label. To check the aforementioned, the regression of the first model is repeated for the sales sample with transactions from November 2016 onwards by only considering offices with A-labels as green properties. Table A.6 shows the green premium that is found with the baseline model in section 6.1.1 (column 1) and the premium that is paid for the A-labelled offices using the labels ranging from B-G as the reference group (column 2). The coefficient in column 2 shows a highly insignificant premium. The results may infer that investors are not willing to pay a significant premium for offices with an A-label relative to a peer group of buildings containing a large group of already energy-efficient buildings (label B and C). Additionally, the coefficients of all other variables stay robust for the alternation. Conclusively, this may be a sign that investors and owners do no yet anticipate the follow-up regulations. Leastwise, it is not yet translated in an additional premium for A-labeled offices.

7 CONCLUSIONS

The putative discussion on the actions that need to be taken for "greening" the built environment has been gaining momentum in the real estate sector over the past few years. Notwithstanding, building improvements in the commercial property sector have been hampered with slow diffusion. The lack of systematic evidence on the capitalization of energy improvements forms a decisive barrier to further capital inflows into building retrofits. For this reason, this paper adds to a better understanding of the economic value of energy efficiency in the Dutch market of office properties.

The hedonic regression models have provided strong evidence that green buildings[22] command a price premium of 7.7% and 7.6% for rental and sales transactions. Moreover, the hedonic model indicates a rental premium of 7.1% and a sales premium of 4.8% for a 10% decrease in EPI. Furthermore, the results for the individual label categories may be indicative of a potential sorting effect. This potential effect may impose that office buildings with labels C, D or E attract investors and tenants that most actively make a tradeoff between the costs and benefits of energy efficiency. Furthermore, the findings provide a potential directive that the willingness to pay for green buildings slightly decreased after the announcement in October 2016 of the prospective label C regulation. This may hint that the willingness to pay for being green decreased since it will become the new standard rather than an instrument to pursue CSR strategies. It has to be noted, that the latter two should be seen as interesting directives for discussion rather than supporting evidence.

Altogether, this study identifies a green premium for Dutch office buildings across different specifications. Moreover, most of the literature on this topic, especially within European markets, use small datasets and consort with identification issues due to the absence of a centralized database. This study contributes by overcoming some of the common identification issues that arise due to the data restrictions. Namely, this study efficiently filters for locational effects by introducing urbanization as a control for micro-locational attributes, resulting in a more parsimonious model. The results provide strong evidence for the modifying impact of urban density with regards to the green premium. It has to be noted that the estimators of urban density are expected to be inflated by many other urban attraction factors. However, the aim of this paper is to identify the unbiased estimator of the green premium rather than the

[22] Buildings are considered green when labeled A, B or C and non-green when labeled D or lower.

unbiased effects of urban density. Additionally, the biased urbanization estimator accurately filters for unwanted locational variance on a 6-digit postal level while strongly reducing the common large vectors of binary variables for locational fixed effects, as used by Kok and Jennen (2012). This method becomes especially relevant within the Dutch commercial real estate, where the common data limitations combined with the high number of parameters needed for the traditional controls for ZIP code effects may result in potential overparameterization. This also explains the relatively high adjusted R-squared (0.660) documented by Kok and Jennen (2012) and the lower adjusted explanatory value (0.245-0.469) of this paper.

This study shows that both tenants and investors are willing to pay for being green. In the context of the announced follow-up regulations[23], the EIB (2016) estimated the payback periods for investments in labeling steps. Their estimations indicate that investors would always be better off by taking a big leap towards an A-label rather than investing in small labeling steps. However, no evidence is found that investors pay an additional premium for offices with an A-label. This may indicate that the market does not anticipate the follow-up regulations, at least it is not yet capitalized in the transactions. These findings are for specific interest for policymakers. In order to accelerate the greening of the built environment, the Dutch government could accentuate these direct and indirect financial effects of energy improvements and the future implications imposed by the follow-up regulations.

This research is susceptible to various limitations, which can mostly be found in the data compartment. As mentioned before, transaction data is hard to obtain due to the absence of a centralized database. To overcome this data collection issue, datasets from several sources are merged resulting in a substantial loss of observations. Given the low matching results, the matching process provides material scope for improvement. The same holds with regards to controls for unobserved heterogeneity. Table A.3 shows all variables that ideally would be included in the hedonic specifications. However, the specifications are bound by the transaction data as provided by Brainbay. Not including several sources of unobserved heterogeneity (e.g. investors attributes) may therefore potentially lead to overestimation of the coefficients. Besides, one may argue that investments in energy improvements may be more plausible for more expensive buildings, accelerating the relative pace of the greening of high-priced offices. If this holds true, it may form threats in terms of causal validity. Lastly, the registration of

[23] The follow-up regulations force the office market towards a mandatory A-label by 2030 and an energy-neutral built environment in 2050.

energy performance is only mandatory when a transaction is completed. Additionally, energy-efficient buildings are more likely to voluntarily register their energy performance. It is argued that the current situation of the energetic quality portrayed by the energy label database is too optimistic (RVO, 2016). For that reason the samples in this paper may not be representative of the complete Dutch office stock, inducing limitations to the implications on a national scale.

To accelerate and realize the Dutch desires of an energy-neutral built environment, the segment of office buildings demands for more future research. As mentioned before, the research perspectives of this paper are conditioned to the access of a sufficient database. Besides enlarging the sample size and obtaining a more complete variable list of required controls (e.g. investor attributes), it would be interesting to delve deeper into the concept of urban density as an alternative control for micro-locational effects.

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9 APPENDICES

A. – Descriptive statistics

Rental sample *Pearson's correlation matrix*	Rental price (ln €/sqm)	Energy index	Size (ln sqm)	New build	Vintage effect	Highly urban	Moderately urban	Rural	Age	Transaction year 2015	Transaction year 2016	Transaction year 2017	Transaction year 2018	Transaction year 2019
Rental price (ln €/sqm)	1.00													
Energy index	0.02	1.00												
Size (ln sqm)	-0.57	-0.03	1.00											
New build	-0.02	-0.07	0.04	1.00										
Vintage effect	-0.15	0.11	0.17	-0.02	1.00									
Highly urban	0.27	0.18	-0.08	0.06	0.04	1.00								
Moderately urban	-0.01	0.03	0.01	-0.03	0.01	-0.45	1.00							
Rural	-0.21	-0.18	0.05	-0.02	-0.04	-0.39	-0.65	1.00						
Age	0.20	0.46	-0.06	-0.05	0.06	0.27	-0.03	-0.20	1.00					
Transaction year 2015	-0.09	0.12	0.01	-0.02	0.39	0.01	0.05	-0.07	0.06	1.00				
Transaction year 2016	0.00	0.05	-0.08	-0.03	0.26	0.04	-0.02	-0.01	0.01	-0.17	1.00			
Transaction year 2017	-0.05	0.01	0.03	0.02	0.06	0.01	0.00	-0.01	0.01	-0.20	-0.30	1.00		
Transaction year 2018	0.00	-0.07	0.04	0.02	-0.28	-0.08	0.01	0.05	-0.06	-0.21	-0.32	-0.37	1.00	
Transaction year 2019	0.13	-0.09	0.00	0.01	-0.34	0.03	-0.03	0.01	0.00	-0.14	-0.21	-0.25	-0.27	1.00

Table A1 *– Pearson's correlation matrix of the relevant variables that are included for the hedonic pricing analysis of the rental sample.*

Sales sample *Pearson's correlation matrix*	Rental price (ln €/sqm)	Energy index	Size (ln sqm)	New build	Vintage effect	Highly urban	Moderately urban	Rural	Age	Transaction year 2015	Transaction year 2016	Transaction year 2017	Transaction year 2018	Transaction year 2019
Rental price (ln €/sqm)	1.00													
Energy index	0.03	1.00												
Size (ln sqm)	-0.25	-0.08	1.00											
New build	0.02	-0.09	0.05	1.00										
Vintage effect	-0.03	0.08	0.11	-0.01	1.00									
Highly urban	0.31	0.15	-0.08	-0.02	0.04	1.00								
Moderately urban	-0.12	-0.05	0.04	0.01	-0.04	-0.62	1.00							
Rural	-0.21	-0.12	0.04	0.02	0.00	-0.41	-0.46	1.00						
Age	0.19	0.42	-0.11	-0.05	-0.01	0.33	-0.17	-0.18	1.00					
Transaction year 2015	-0.03	0.04	0.04	0.01	0.27	0.00	0.00	0.00	0.06	1.00				
Transaction year 2016	-0.08	0.04	0.04	0.04	0.23	0.00	0.01	-0.02	-0.01	-0.10	1.00			
Transaction year 2017	-0.02	0.02	0.00	-0.01	0.10	0.01	-0.01	-0.01	0.02	-0.13	-0.21	1.00		
Transaction year 2018	0.01	-0.05	-0.01	0.00	-0.15	-0.02	0.00	0.02	-0.06	-0.17	-0.28	-0.37	1.00	
Transaction year 2019	0.09	-0.02	-0.04	-0.03	-0.26	0.00	-0.01	0.00	0.02	-0.14	-0.24	-0.31	-0.41	1.00

Table A2 *– Pearson's correlation matrix of the relevant variables that are included in the hedonic pricing analysis of the sales sample.*

Table A3 – Variable overview

Variable	Measure	Description	Expected Effects	Type
Dependent variables				
Rental price	ln price €/sqm	The stated price for which the office space is rented		continuous
Sales price	ln price €/sqm	The stated price for which the office space is sold		continuous
Investment attributes				
Duration leasing contract	*nr*	*The length of the leasing contract registered at the transaction*	+	*nr*
Investor characteristics	*nr*	*Characteristics of the investor, e.g. institutional/private, nationality, purpose*	+/-	*nr*
Structural attributes				
Size	Ln transaction size sqm	Size of the property floor that is rented/sold measured in square meters	-	continuous
Age	2019 - construction year	Age of the office building in terms of construction relative to the year 2019	-	continuous
Energy efficiency	EPI	The continuous score of the modeled energy consumption	-	continuous
Green	EPC	Takes on a value 1 if labeled A-C and 0 if labeled D-G	-	dummy
Parking facilities	number of parking lots	The total amount of stated parking lots	+	continuous
Parking facilities	presence parking lot	Takes on a value 1 if there is at least one parking lot and 0 otherwise	+	dummies
Label vintage effect	registration year – transaction year	The willingness to pay for energy efficiency could diminish annually upon issuance, this is the so-called 'label vintage effect'.	-	
Locational attributes				
Micro-locational effects	postal code	Measured in the first digit of the Dutch postal code	na	dummies
Urban density	urban density rank	Urban density measured in number of addresses in km^2 and ranked from highly urban (>2500), moderately urban (1000-2500) to rural (<1000), with highly urban as the reference group	-	dummies
Accessibility	*nr*	*Accessibility with regards to public transport or nearest highway*	+	*nr*
Macro effects				
Transaction year	transaction year	The year in which the office space has been sold/rented	na	dummies
Transaction month	transaction month	The month in which the office space has been sold/rented	na	dummies

Table A3 *– Variable overview that shows all variables required to perform the most ideal hedonic price analysis for the purpose of this paper. However, due to data restrictions, we were unable to include some variables, which are denoted with 'not reported'. For the sake of completeness and future research purposes, these variables are included in the overview.*

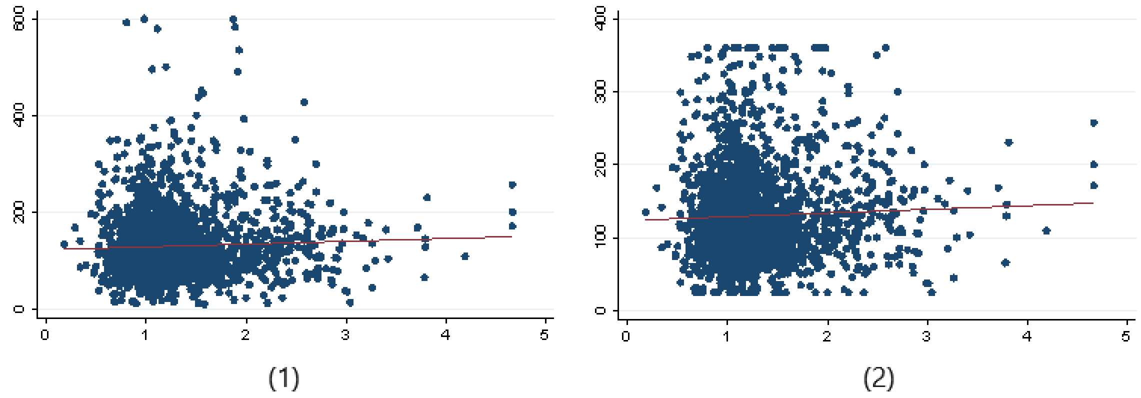

Figure A1 *– Scatterplot of the EPI (x-axis) and the transaction rental price per sqm (y-axis), including both ex-ante and ex-post winsorized price per sqm.*

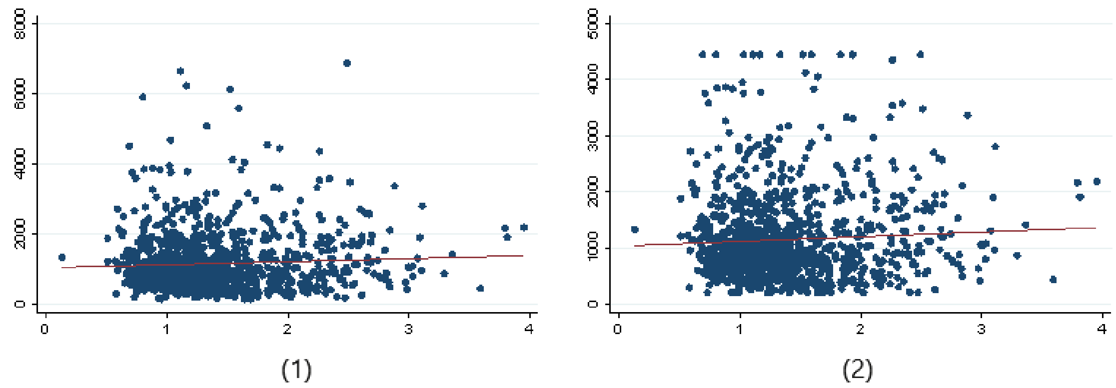

Figure A2 *– Scatterplot of the EPI (x-axis) and the transaction rental price per sqm (y-axis), including both ex-ante and ex-post winsorized price per sqm.*

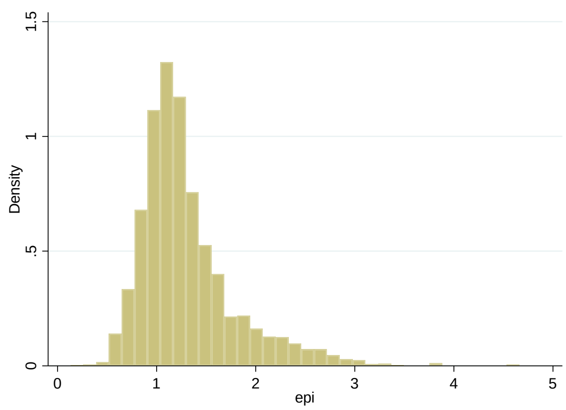

Figure A3 *– Histogram of the distribution of the EP index (x-axis) of the rental- and sales transactions combined, with the density on the y-axis.*

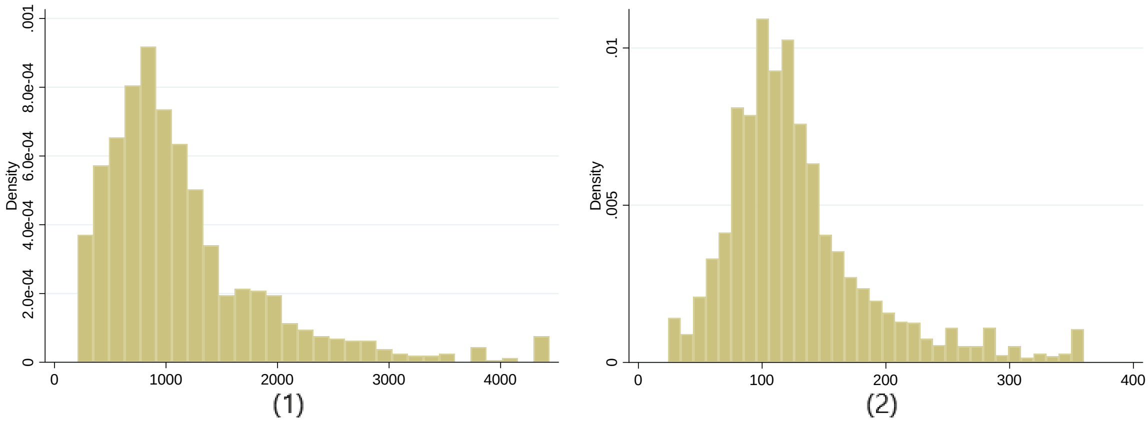

Figure A4 *– Histogram of the winsorized distribution of both the sales (1) and the rental (2) transactions with the transaction prices on the x-axis and the density on the y-axis.*

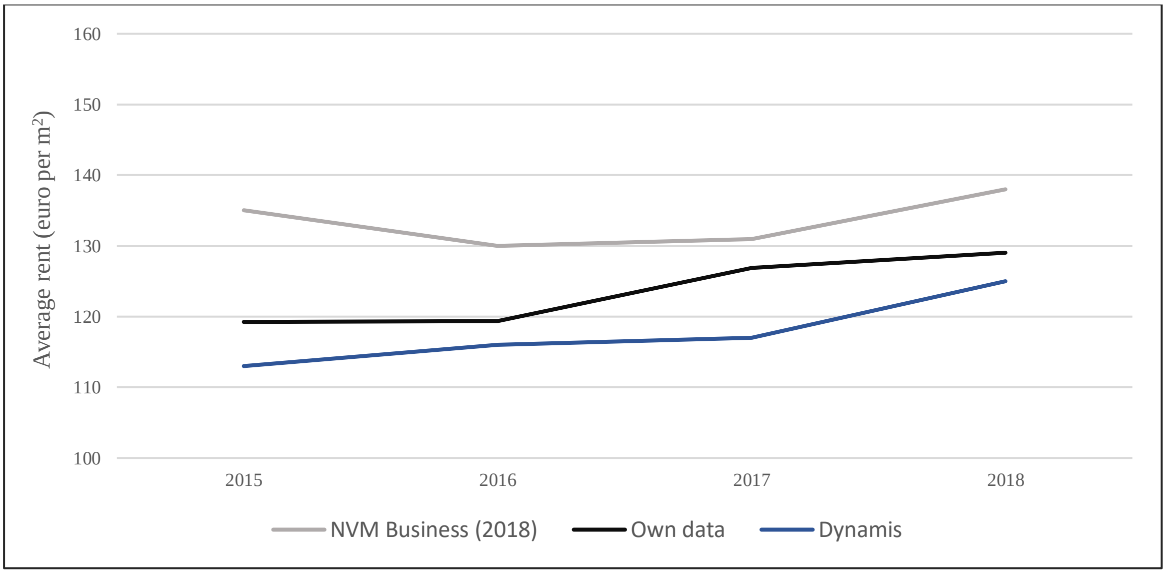

Figure A5 *– Price development of the rental prices based on the rental sample used in the regression analysis and the annual reports on the Dutch office market from NVM Business (2019) and Dynamis (2019).*

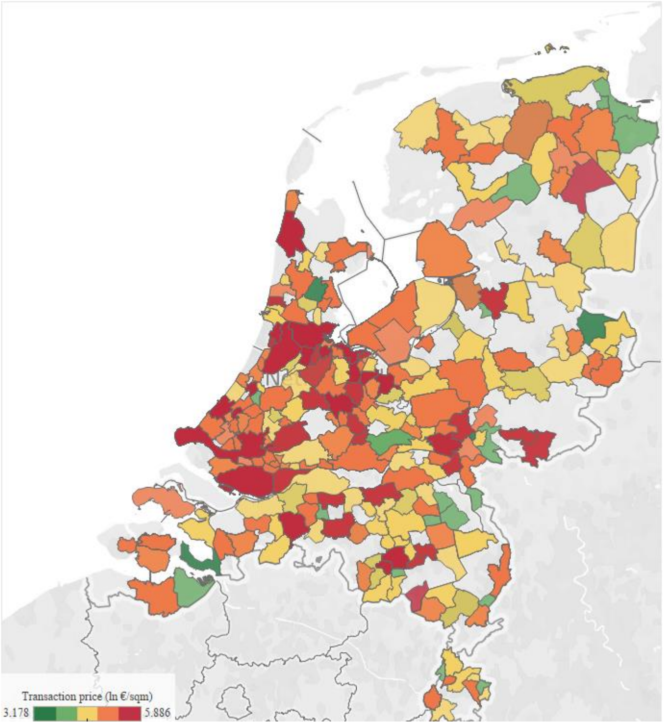

Figure A6 *– Heat map of the average transactional rent price per municipality, denoted by the logarithmic function of the rental price in €/sqm.*

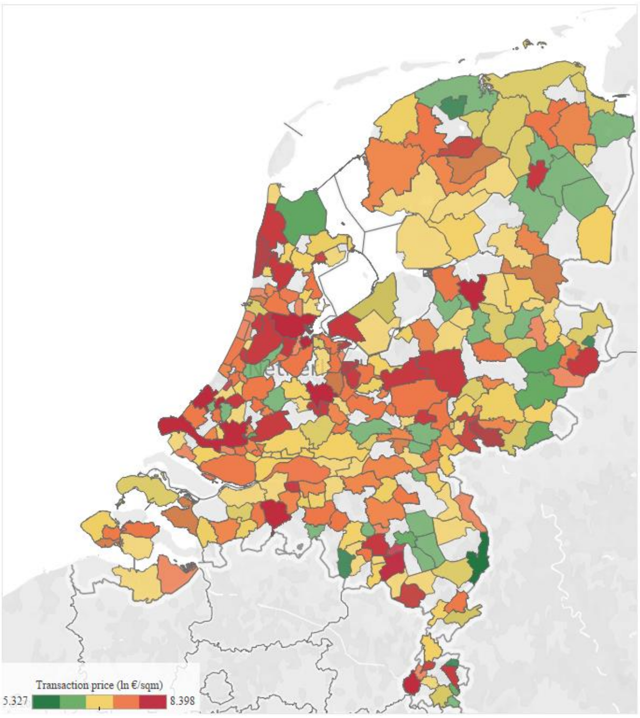

Figure A7 *– Heat map of the average transactional sales price per municipality, denoted by the logarithmic function of the sales price in €/sqm.*

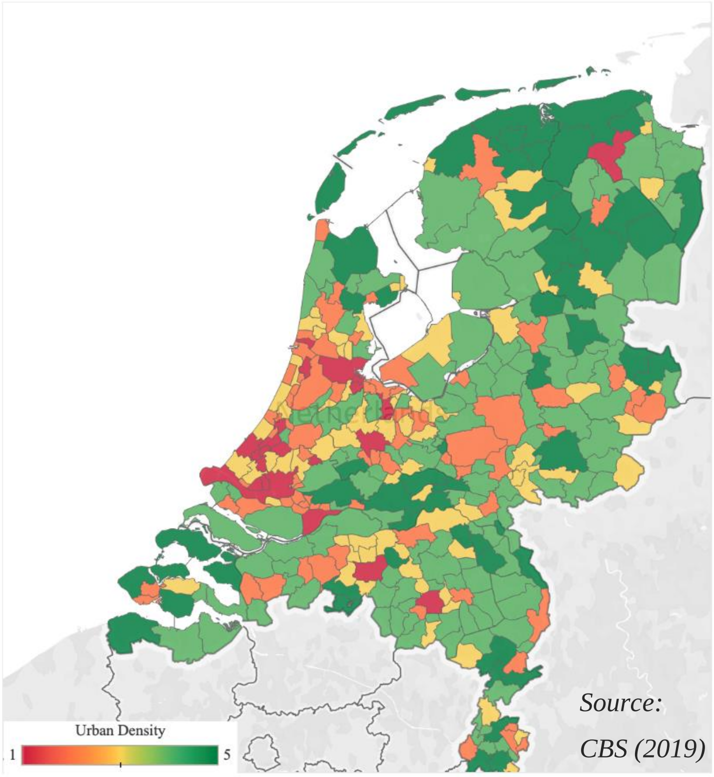

Figure A8 *– Heat map of the Dutch urban density per municipality provided by the Central Agency of Statistics.*

B. – Complete regression results

Table B1 – Complete regression results of model 1 for both transactional rent and sales prices

	Logarithm transactional rental price			Logarithm transactional sales price		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Green	0.077***			0.076**		
(A, B or C)	(0.020)			(0.034)		
Label Category [A]						
A		0.023			0.019	
		(0.030)			(0.051)	
B		0.044			0.064	
		(0.034)			(0.056)	
C		0.064**			0.078	
		(0.031)			(0.051)	
E		-0.068*			-0.007	
		(0.039)			(0.062)	
F		-0.039			-0.180**	
		(0.048)			(0.070)	
G		-0.049			0.007	
		(0.036)			(0.054)	
Energy Index			0.071***			0.048*
(ln inverse)			(0.022)			(0.036)
Size (log sqm)	-0.089***	-0.089***	-0.089***	-0.300***	-0.301***	-0.300***
	(0.008)	(0.008)	(0.008)	(0.014)	(0.014)	(0.014)
Label vintage effect	-0.009*	-0.008	-0.009*	-0.012	-0.012	-0.011
	(0.005)	(0.005)	(0.005)	(0.011)	(0.011)	(0.011)
Moderately urban [B]	-0.175***	-0.175***	-0.171***	-0.189***	-0.197***	-0.190***
	(0.019)	(0.020)	(0.020)	(0.037)	(0.037)	(0.037)
Rural [B]	-0.270***	-0.268***	-0.265***	-0.335***	-0.335***	-0.332***
	(0.023)	(0.023)	(0.023)	(0.040)	(0.040)	(0.040)
Construction age [C]						
0-10	0.232***	0.238***	0.226***	0.263***	0.300***	0.295***
	(0.053)	(0.054)	(0.054)	(0.100)	(0.101)	(0.100)
11-20	0.124***	0.124***	0.124***	0.181***	0.206***	0.217***
	(0.044)	(0.045)	(0.045)	(0.063)	(0.065)	(0.063)
21-30	0.101**	0.095**	0.099**	0.097	0.111*	0.124**
	(0.044)	(0.045)	(0.045)	(0.061)	(0.062)	(0.061)
31-40	0.040	0.029	0.036	0.074	0.094	0.090
	(0.047)	(0.048)	(0.048)	(0.064)	(0.066)	(0.065)
41-50	0.037	0.031	0.031	0.013	0.033	0.023
	(0.051)	(0.051)	(0.051)	(0.065)	(0.066)	(0.065)
61-70	0.187***	0.187***	0.190***	0.124	0.125	0.130
	(0.060)	(0.060)	(0.060)	(0.086)	(0.086)	(0.086)
71-80	0.409***	0.408***	0.417***	0.236*	0.241*	0.241*
	(0.103)	(0.104)	(0.103)	(0.142)	(0.142)	(0.143)
81-90	0.197***	0.202***	0.192***	0.205**	0.202**	0.218**
	(0.062)	(0.062)	(0.062)	(0.085)	(0.085)	(0.085)
91-100	0.273***	0.272***	0.274***	0.419***	0.437***	0.427***
	(0.062)	(0.062)	(0.062)	(0.095)	(0.095)	(0.095)
>100	0.331***	0.329***	0.334***	0.462***	0.462***	0.473***
	(0.047)	(0.047)	(0.047)	(0.064)	(0.064)	(0.064)
Postal codes [D]						
2XXX	-0.143***	-0.146***	-0.144***	0.074	0.064	0.077
	(0.027)	(0.027)	(0.027)	(0.048)	(0.048)	(0.048)
3XXX	-0.074***	-0.074***	-0.077***	0.037	0.034	0.037
	(0.023)	(0.023)	(0.023)	(0.047)	(0.047)	(0.047)
4XXX	-0.181***	-0.181***	-0.185***	-0.053	-0.059	-0.053
	(0.033)	(0.033)	(0.033)	(0.055)	(0.054)	(0.055)
5XXX	-0.199***	-0.200***	-0.199***	-0.009	-0.017	-0.006
	(0.032)	(0.032)	(0.032)	(0.052)	(0.052)	(0.052)

(Table continues on the next page)

6XXX	-0.183***	-0.179***	-0.179***	-0.124**	-0.122**	-0.124**
	(0.033)	(0.033)	(0.033)	(0.050)	(0.050)	(0.050)
7XXX	-0.266***	-0.265***	-0.267***	-0.169***	-0.173***	-0.168***
	(0.035)	(0.035)	(0.035)	(0.053)	(0.053)	(0.054)
8XXX	-0.264***	-0.268***	-0.273***	-0.246***	-0.246***	-0.247***
	(0.047)	(0.048)	(0.047)	(0.062)	(0.061)	(0.062)
9XXX	-0.272***	-0.272***	-0.269***	-0.222***	-0.235***	-0.218***
	(0.040)	(0.040)	(0.040)	(0.062)	(0.062)	(0.062)
Macro effects [E]						
2016	-0.021	-0.018	-0.024	0.143***	0.140***	0.139***
	(0.040)	(0.040)	(0.040)	(0.052)	(0.052)	(0.052)
2017	0.051*	0.052*	0.049*	0.168***	0.164***	0.166***
	(0.038)	(0.038)	(0.038)	(0.052)	(0.052)	(0.052)
2018	0.079**	0.081**	0.079**	0.243***	0.242***	0.239***
	(0.038)	(0.038)	(0.038)	(0.055)	(0.055)	(0.055)
2019	0.127***	0.128***	0.125***	0.371***	0.372***	0.369***
	(0.039)	(0.039)	(0.039)	(0.063)	(0.063)	(0.063)
Constant	5.197***	5.235***	5.341***	8.504***	8.529***	8.581***
	(0.071)	(0.075)	(0.078)	(0.109)	(0.116)	(0.125)
Observations	2,497	2,497	2,497	1,126	1,126	1,126
R-squared	0.253	0.255	0.252	0.484	0.490	0.483
Adj. R-squared	0.245	0.245	0.243	0.469	0.474	0.471

Note: Standard errors in parentheses. . ***, **, *: significant at 10%, 5% and 1% respectively.

[A] Reference group is label D

[B] Reference group is ‘highly urban’

[C] Reference group is ‘51-60’

[D] Reference area is 1XXX

[E] Reference year is 2015

Table B1 *– Overview of the complete regression results of the first model that is specified in 4.1.1 to test the green premium. Models 1,2 and 3 uses the logarithm of the transactional rental price and models 4,5 and 6 uses the logarithm of the transactional rental price as the dependent variable.*

Table B2 - Results of model (2) and model (3) with the logarithm the transactional rental price (€/sqm) as the dependent variable

	Rental price (ln €/sqm)			
VARIABLES	Model (2)		Model (3)	
Green *(A, B or C)*	0.088**	(0.038)	0.131***	(0.029)
Green * Afterpolicy	-0.014*	(0.039)		
Green * urbaan			-0.065**	(0.039)
Green * rural			-0.124***	(0.048)
Moderately urban[A]	-0.175***	(0.019)	-0.130***	(0.032)
Rural[A]	-0.270***	(0.023)	-0.175***	(0.042)
Label vintage effect	-0.009*	(0.005)	0.009*	(0.005)
Size (log sqm)	-0.089***	(0.008)	-0.089***	(0.008)
Construction age[B]				
0-10	0.233***	(0.053)	0.234***	(0.053)
11-20	0.124***	(0.044)	0.128***	(0.044)
21-30	0.102**	(0.044)	0.103**	(0.044)
31-40	0.040	(0.047)	0.035	(0.047)
41-50	0.038	(0.051)	0.039	(0.051)
61-70	0.187***	(0.060)	0.185***	(0.060)
71-80	0.410***	(0.103)	0.405***	(0.103)
81-90	0.197***	(0.062)	0.203***	(0.062)
91-100	0.274***	(0.062)	0.285***	(0.062)
<100	0.331***	(0.047)	0.342***	(0.048)
Postal areas[C]				
2XXX	-0.142***	(0.027)	-0.140***	(0.027)
3XXX	-0.072***	(0.023)	-0.072***	(0.023)
4XXX	-0.180***	(0.033)	-0.183***	(0.033)
5XXX	-0.198***	(0.032)	-0.195***	(0.032)
6XXX	-0.180***	(0.033)	-0.179***	(0.033)
7XXX	-0.266***	(0.035)	-0.261***	(0.035)
8XXX	-0.265***	(0.047)	-0.263***	(0.047)
9XXX	-0.272***	(0.040)	-0.267***	(0.040)
Macro effects[D]				
year 2016	-0.027	(0.040)	-0.022	(0.040)
year 2017	0.043*	(0.045)	0.054*	(0.038)
year 2018	0.063**	(0.044)	0.080**	(0.038)
year 2019	0.102**	(0.045)	0.126***	(0.039)
Constant	5.219***	(0.072)	5.161***	(0.072)
Observations	2,497		2,497	
R-squared	0.253		0.256	
Adj. R-squared	0.244		0.247	

Note: Standard errors in parentheses. . ***, **, *: significant at 10%, 5% and 1% respectively.
[A] Reference group is 'highly urban'
[B] Reference group is '51-60'
[C] Reference area is 1XXX
[D] Reference year is 2015

Table B2 *– Overview of the complete regression results of the second model that is specified in 4.1.2 to test the stationarity. Models 1 uses the logarithm of the transactional rental price and model 2 uses the logarithm of the transactional rental price as the dependent variable.*

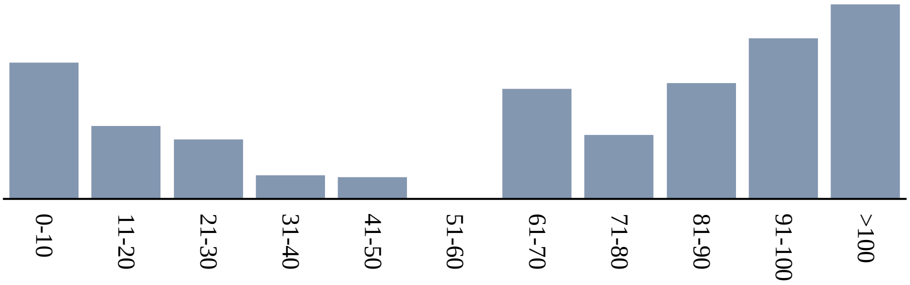

Figure B1 *– Visualization of the effects of the binary variables for construction age that are observed for the rental sample (Table B.1, column 1)*

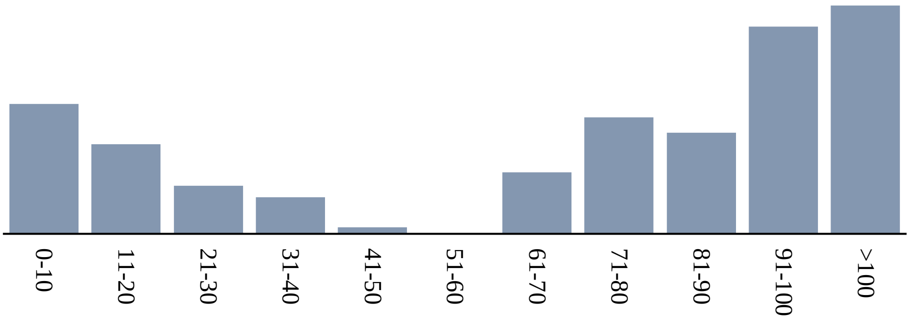

Figure B2 *– Visualization of the effects of the binary variables for construction age that are observed for the sales sample (Table B.1, column 4)*

```
. test GreenUrban=GreenRural=0

 ( 1)  GreenUrban - GreenRural = 0
 ( 2)  GreenUrban = 0

       F(  2,  2466) =    4.17
            Prob > F =    0.0156

.
```

Figure B3 *– The F-statistic for joint significance testing of the concept of urban density as a moderator variable as specified in model 3.*

C. – Robustness results

	Rental Price (ln €/sqm)		Sales Price (ln €/sqm)	
VARIABLES	(1)	(2)	(3)	(4)
Green *(A, B or C)*	0.073*** (0.020)		0.071** (0.040)	
Energy Index *(inverse ln)*		0.069** (0.031)		0.040** (0.057)
Other controls				
Age	Yes	Yes	Yes	Yes
Label vintage effect	Yes	Yes	Yes	Yes
Macro effects	Yes	Yes	Yes	Yes
Postal codes	Yes	Yes	Yes	Yes
Size (log sqm)	Yes	Yes	Yes	Yes
Urban density	Yes	Yes	Yes	Yes
Observations	1,571	1,571	5,070	5,070
R-squared	0.219	0.217	0.298	0.296

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C1 *– Results of the robustness check where the regression analysis is performed on the sample that is matched according to ID codes that exclude the suffix.*

	Rental Price (ln €/sqm)		Sales Price (ln €/sqm)	
VARIABLES	(1)	(2)	(3)	(4)
Green *(A, B or C)*	0.042** (0.038)		0.037* (0.035)	
Energy Index *(inverse ln)*		0.042* (0.051)		0.035 (0.048)
Other controls				
Age	Yes	Yes	Yes	Yes
Label vintage effect	Yes	Yes	Yes	Yes
Macro effects	Yes	Yes	Yes	Yes
Postal codes	Yes	Yes	Yes	Yes
Size (log sqm)	Yes	Yes	Yes	Yes
Urban density	Yes	Yes	Yes	Yes
Observations	3,422	3,422	1,276	1,276
R-squared	0.223	0.222	0.477	0.479

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C2 *– Results of the robustness check where the regression analysis includes observations with non-active energy labels.*

VARIABLES	Rental Price (ln €/sqm) (1)	(2)	(3)	(4)	Sales Price (ln €/sqm) (5)	(6)	(7)	(8)
Green	0.077***	0.080***			0.076**	0.077**		
(A, B or C)	(0.020)	(0.051)			(0.034)	(0.034)		
Energy Index			0.071***	0.076***			0.048*	0.048*
(inverse ln)			(0.022)	(0.023)			(0.036)	(0.036)
Urban density								
Categories	Yes	No	Yes	No	Yes	No	Yes	No
Continuous score	No	Yes	No	Yes	No	Yes	No	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,497	2,497	2,497	2,497	1,276	1,276	1,276	1,276
R-squared	0.253	0.256	0.252	0.255	0.484	0.485	0.483	0.483

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C3 *– Results of the robustness check where the regression analyses are performed with the categorization (columns 1,3,5 & 7) and the continuous score (columns 2,4,6 & 8) for the degree of urban density.*

VARIABLES	Rental Price (ln €/sqm) (1)	(2)	(3)	(4)	Sales Price (ln €/sqm) (5)	(6)	(7)	(8)
Green	0.077***	0.056**			0.076**	0.047*		
(A, B or C)	(0.020)	(0.189)			(0.034)	(0.034)		
Energy Index			0.071***	0.051**			0.048*	0.011
(inverse ln)			(0.022)	(0.029)			(0.036)	(0.052)
Postal codes								
1-digit	Yes	No	Yes	No	Yes	No	Yes	No
2-digit	No	Yes	No	Yes	No	Yes	No	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,497	2,497	2,497	2,497	1,276	1,276	1,276	1,276
R-squared	0.253	0.357	0.252	0.356	0.484	0.568	0.483	0.567

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C4 *– Results of the robustness check where the regression analyses are performed with one-digit postal codes (columns 1,3,5 & 7) and 2-digit postal codes (columns 2,4,6 & 8) as locational control variables.*

	Sales Price (ln €/sqm)	
VARIABLES	(1)	(2)
Green	0.076**	
(A, B or C)	(0.034)	
A-Label[A]		-0.019
		(0.035)
Other controls		
Age	Yes	Yes
Vintage effect	Yes	Yes
New build	Yes	Yes
Urban density	Yes	Yes
Postal codes	Yes	Yes
Macro effects	Yes	Yes
Observations	1,126	1,126
R-squared	0.484	0.482

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

[A] Reference group are energy labels B, C, D, E, and G

Table C5 *– Results of the robustness check where the baseline regression is performed with the variables of interest being: green labels using non-green labels as reference (column 1), and A-labels using all other labels as reference (column 2).*