EPConomics: Unveiling the economic potential of energy efficiency in Dutch retail real estate

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J.S Zhang
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Abstract

The quest for environmentally conscious practices has become a paramount concern in the real estate sector, with a growing emphasis on reducing carbon emissions, as they are found to be responsible for a significant 36 percent of total global energy consumption. Energy Performance Certificates (EPCs) play a crucial role in advancing energy efficiency and facilitating the seamless transition toward achieving overarching national and EU regulatory energy goals. A growing body of research has explored the connection between energy performance attributes and the impact of EPCs. Although these studies consistently reveal the existence of a pricing effect, more recent investigations suggest that the relationship is intricate and inconclusive, especially when considering data constraints and varying model specifications.

In this research, compelling evidence is presented regarding the economic advantages of EPCs in the Dutch retail market. The study draws from the principles of Industrial Ecology, with a specific emphasis on understanding the systemic relationships between society, the economy, and the natural environment. By analyzing historical rental and sale market transactions from 2015 to 2021, this research presents some of the earliest evidence on the economic value of energy certification in the retail sector. Stationary premia for higher EPC-certified rental transactions are roughly 11 percent, on a price per square meter basis. Selling prices of energy-efficient transactions are more marginal and complex, especially in light of data constraints and changing model specifications. This linkage between sustainability and financial benefits creates a strong incentive for investors, and businesses, alike to adopt energy-efficient measures, since currently, substantial upfront, often on-balance, capital costs are incurred to carry out energy retrofits of existing building stock. This study also stands out as one of the first to conduct spatial analyses of EPCs for the retail sector, providing valuable insights for informed policy-making while considering geographic variation. The absence of a concrete plan within Dutch national regulations for enhancing energy efficiency in retail buildings and aligning them with overarching climate goals in the built environment underscores the importance of this study. In the new age of economic activities where transparency is the zeitgeist, this research provides empirical evidence to mobilize responsible investments into energy-efficient buildings and shift the paradigm from merely managing downside risks to benefiting stakeholders and improving capital efficiency.

Keywords: Energy Efficiency; Energy Transition; Retail; Green Premium; Sustainable Real Estate Investment

Contents

Nomenclature

This page provides a list of abbreviations used throughout the document.

Terminology

Abbreviation	Definition
BIC	Bayesian Information Criterion
BREEAM	Building Research Establishment Environmental Assessment Method
CAI	Customer Attraction Index
CBS	Statistics Netherlands *Centraal Bureau voor de Statistiek*
CRSM	Corporate Real Estate Sustainability Management
CSR	Corporate social responsibility
DGBC	Dutch Green Building Council
EI	Energy Index
EOL	End-of-life
EPI	Economic Potential Index
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EU	European Union
ESG	Environmental, social, governance
GHG	Greenhouse gases
GIS	Geographical Information Software
LEED	Leadership in Energy and Environmental Design
REIT	Real estate investment trust
SQM	Square meterage

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1 Introduction

Over the past few decades, building codes around the world have become stricter and the real estate sector, as a whole, has become better at delivering energy-efficient building designs. These buildings have pioneered countless material, product, and process innovations that have impacted supply chains for reduced carbon emissions, as well as the construction and operations of these buildings (WBCSD, 2021). However, in spite of the trillion-dollar push, worldwide, towards building sustainable real estate, 38 percent of all energy-related GHG emissions and 39 percent of total CO_2 emissions are still currently a result of the existing built environment (United Nations Environment Programme, 2017).

Energy efficiency plays a leading role in the sustainability agenda of the built environment that seeks to lessen the ecological pressures in areas such as energy, material extraction, recycling, pollution, and water usage. Currently, the building sector is responsible for 36 percent of total global energy consumption. Of which, 30 percent is used during the building's operation phase and the remaining 6 percent for construction-related activities (UNEP, 2022-11). Energy consumption, moreover, is not on the decline: a study conducted by Levesque et al. (2018) estimates that global energy consumption will triple by 2100 due to increasing floor area demand, the economic growth of the Global South, and limited improvements in energy efficiency. This may bring about severe consequences to inflation and poverty rates, as well as, an increased likelihood of economic recession (Santamouris & Vasilakopoulou, 2021), contemporaneously experienced, due to the energy crisis in Europe. This leaves the real estate sector vulnerable to volatile prices for the demand of energy and raw materials. The combination of these factors highlights the critical importance of addressing energy-related issues proactively and implementing sustainable measures to safeguard economic stability and the well-being of the populace. Within this sector lies the immense potential to wield a significant impact on curbing emissions and mitigating such crises in the future. (Enkvist et al., 2007).

Given the escalating acknowledgement of, and concerns for unbridled energy consumption and therefore broader environmental impacts, there has been an emphasis on, and policy redirection towards, enhancing the environmental efficiency of buildings. The reduction of energy consumption has emerged as a central element of governmental policies due to measurability and causality, with prominent objectives including the attainment of carbon neutrality targets (Zuo et al., 2012). Accordingly, the

EU has pushed for legislation and directives targeting energy performance. The Energy Performance of Buildings Directive (EPBD) is the main EU legislative instrument to promote energy efficiency within the built environment. Born in January of 2002, the Directive wishes to promote policies that will aid in the decarbonization of existing and new building stock by implementing Energy Performance Certificates (EPC) for residential and commercial properties. EPCs are provided to the owner or tenant when a property is sold or rented.

This disseminated into the Netherlands, initially, for all residential dwellings that are listed for rent or sale, with non-residential and public buildings following suit in 2008. In order to comply with current and *future* regulatory requirements, it is imperative to adopt a holistic approach that encompasses the anthropogenic activities of the building sector. Maintained by the Dutch Ministry of Economic Affairs, EPC labels are based on energy performance assessments and label grades vary from G, for particularly inefficient properties, to A++++ for highly efficient properties. Voluntary eco-labels such as BREEAM, LEED, and Green Star have also proliferated in the real estate sector. This market-led sustainability agenda exceeds current regulatory policies and potentially offers an opportunity to assess the financial impact of a broader *sustainability* discourse on real estate assets. Nevertheless, the majority of research on voluntary labels has primarily focused on the United States, as prominent labeling schemes like LEED have not yet fully penetrated the European property markets. Amid the mounting pressures faced by both retailers and investors, the question of how sustainability, particularly energy efficiency, influences real estate investment performance remains a subject of ongoing debate. Consequently, many investors remain hesitant to invest in energy-saving measures and energy retrofitting for existing building stock. The uncertainty surrounding the financial impact of sustainability initiatives presents a challenge, prompting a cautious approach from investors in navigating this complex terrain (Kok & Jennen, 2012).

1.1. Background

Literature around the environmental performance of built assets of the past decade has exceedingly honed in on the construction and technological implementation for new building stock in lieu of their implications for financial stakeholders (Dalton & Fuerst, 2018). Yet, the enhanced construction technologies to reduce carbon emissions do not impact upon the existing stock, comprising approximately 85-90 percent of the total building stock (Fawcett & Boardman, 2009). And while the environmental benefits of investing in green real estate yield tangible and measurable effects, its financial impacts and returns are a part of the ongoing literary investigation.

There is a considerable and growing body of literature that suggests real estate with high environmental performance brings forth a myriad of benefits to both occupiers and investors. However, literature investigating the dollar value of energy performance, or the broader *green premium* is disjointed and partly inconclusive (Dalton & Fuerst, 2018). Two categories of environmental certification exist within the literature as performance controls. One category is focused solely on energy performance such as EPCs and Energy Star (an equivalent in the United States). The other category revolves around voluntary eco-certification, characterized by its geographical specificity and alignment with diverse and varying environmental agendas. These certifications encompass a wide range of objectives, including but not limited to water usage, public health, and waste management. The rating scale of these different certifications varies greatly: of all certification programs, Leadership in Energy, Environmental Design (LEED), and Building Research Establishment Environmental Assessment Method (BREEAM) are (inter)nationally the most used and valued the environmental performance of buildings outside of energy performance (Brown & Watkins, 2015). The presence of a voluntary environmental label and superior environmental performance are not necessarily synonymous (Fuerst & McAllister, 2011a) and in practice, eco-certifications are often used as a surrogate for *green buildings* which may lead to issues concerning green-washing. Most of the voluntary labels are not fully comparable; they change over time, primarily relate to new-builds, and most importantly, highlight a lack of firm understanding of what constitutes a green building. This does not undermine the need for these rating systems or is a critique of them, but rather an acknowledgment of their role as a benchmark for the shift to increased levels of sustainability and potential energy efficiency in the real estate market. Energy performance was selected as the metric of choice due to its inherent measurability and causality. It is due to the lack of data, partially because of its voluntary nature, and aggregated sustainability variables that EPCs are selected over voluntary eco-labels as the metric to measure the sustainability of a building. Energy consumption plays a substantial role in the environmental impact of the built environment and this paper will address energy-efficient properties as "*sustainable* buildings". Properties focused on voluntary eco-labels will be addressed as "*green* buildings". Figure 1.1 illustrates a timeline of environmental certification development and adoption worldwide for commercial properties.

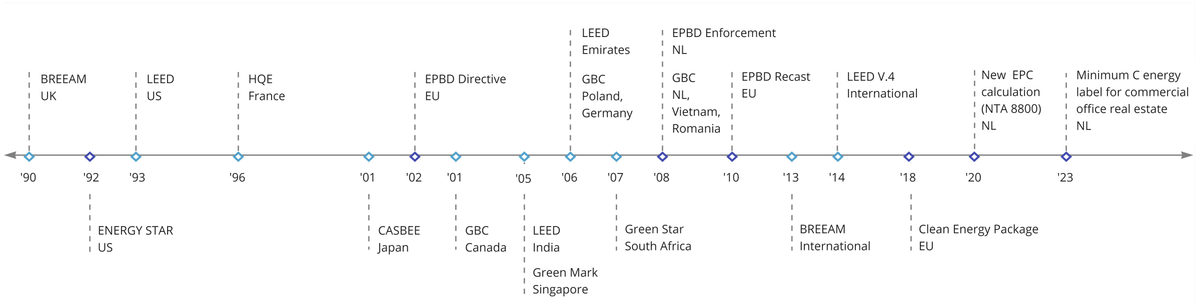

Figure 1.1: Evolution of sustainable commercial labeling: a global timeline; source: author.

Findings from prior research

Prior literature on *green* premiums mostly looked into the US market with a focus on residential and commercial office properties (due to the vast amount of available data in that region). They can be further categorized into single-family homes, condos, and offices, in descending order of the frequency of publications. One of the most important findings from the body of research comes from the random-effects meta-analysis conducted by Dalton and Fuerst (2018) that aggregated 42 global studies to examine the relationship between environmental certification and property transaction prices. They produced rental and sales premiums with weighted mean effects of 6.0 percent and 7.6 percent respectively when controlling for the broader residential and commercial markets with certification measures of EPC, Energy Star, BREEAM, LEED, Green Mark, NABERS, and mixed certifications. While the final effects are highly significant, the analysis showed high statistical heterogeneity and potential publication bias. To mitigate the high degree of heterogeneity, further subgroup analysis based on different markets, certification measures, and property types was conducted. It was determined that the US market, commercial property, residential property, LEED, and Energy Star subgroups contained a sufficient number of studies to estimate significant premiums. The EPC subgroup contained confidence levels of zero and high heterogeneity even within its own subgroup, which can suggest that the green premium varies throughout Europe. It is also important to note that the commercial property subgroup did not contain any retail sector properties or transactions, highlighting once again the knowledge gap on the value of energy performance in the retail sector.

Empirical research has found a positive correlation between tangible and intangible benefits for green asset owners and occupiers alike (Eichholtz et al., 2010, 2013). Tangible benefits can include lower operating costs over time (Ahn et al., 2013; Op't Veld & Vlasveld, 2013), increased occupancy (Sayce et al., 2010), higher liquidity (Devine & Kok, 2015; Pheng Low et al., 2014; Pulselli et al., 2007), lower asset depreciation, and higher rent prices (Dalton & Fuerst, 2018); whereas intangible benefits include future-proofing against decreased value due to obsolescence (a browning effect), a reduction of long-term risk, and image, branding and reputational advantages (Arif et al., 2009; Serpell et al., 2013). From the investor's perspective the reduction of long-term risks, coupled with engaging in CSR credentials is seen as critical in investment decisions. Furthermore, a positive correlation has been observed with a tenant's willingness to pay for the benefits derived from these sustainable practices. This correlation, however, fluctuates across different time frames, geographical locations, and building types, underscoring the dynamic nature of the relationship between sustainable features and their perceived value in the real estate market (Simons et al., 2014). These sustainable value drivers will be explored in greater detail along with an in-depth literature review in Chapter 2.

On the nature of Dutch retail

The Netherlands, being one of the most densely populated countries globally, has consequently developed a highly concentrated retail structure (Berghauser Pont & Haupt, 2007). It is also one of Europe's best-performing retail markets- in contrast to numerous European countries, retail establishments in the Netherlands are predominantly situated at the core of local communities, reflecting their integral role in the socio-economic fabric. The average consumer is used to visiting supermarkets more than three times a week, with over half arriving by bicycle or on foot (Ecorys, 2016). The retail sector provides employment for over 8 percent of the working population and generates 93 billion euros in revenue-roughly 14 percent of total GDP (Statistics Netherlands, 2019).

The Dutch retail landscape is characterized by a spatial network of peripheral residential boulevards and inner cities in close proximity to each other (Colliers, 2021). Location typologies are typically divided into city centers, regional centers, and regional centers. In Dutch city centers, numerous small shops are often housed within historic buildings to form a concentration of shopping streets - high streets-attracting a significant number of residents, commuters, and tourists (Zhang et al., 2023). Regional centers, both large and small, are vital commercial hubs that serve a wide catchment area, attracting shoppers from both nearby towns and rural areas by providing a wide variety of diverse goods and services. District centers, on the other hand, are more localized retail destinations situated within residential neighborhoods. They cater primarily to the immediate surrounding community, providing convenience-oriented retail services such as supermarkets and local shops (Borchert, 1988). As a result of the ease of accessibility coupled with cultural habits, the presence of large regional shopping centers is limited, and local authorities impose restrictions on the establishment of big box retail outlets on the outskirts of cities (van der Krabben, 2009). Attempts to introduce these hypermarkets have not been very successful, thus far (Ecorys, 2016).

1.2. Problem statement

Currently, substantial upfront, often on-balance, capital costs are incurred to carry out energy retrofits of existing building stock. The apparent lack of investments in energy efficiency and sustainability is further impacted by the current credit constraints among real estate investors as a direct result of financial downturns in the market (Kok & Jennen, 2012). The economic performance and valuation of energy-efficient buildings play a crucial role in providing further incentives for investment and the supply of energy-efficient building stock. In the Dutch context, the government has set ambitious targets to regulate and even halt operations for office buildings transacted below an EPC grade label of C (Colliers, 2021). And while huge strides have been made in the residential sector due to the EPBD, building improvements in the commercial property sector lag behind and have not, on a large scale, taken off (Op't Veld & Vlasveld, 2013).

The Principle-Agent problem

The difficulty of articulating a so-called business case for these sustainable, energy-efficient properties lies partly in a fundamental principle-agent problem known as the *Circle of Blame* between investors, developers, builders, and tenants, illustrated in Figure 1.2 (D. Cadman, 2000).

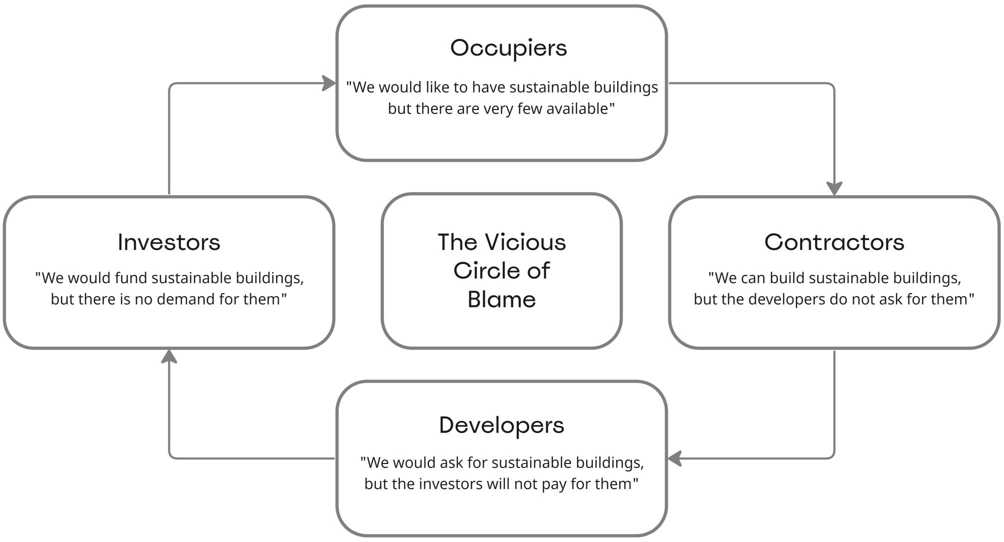

Figure 1.2: The Vicious Circle of Blame; source: author, adapted from Cadman (2000).

In the absence of continuously traded and securitized markets, valuations, act as a surrogate for property prices, playing a vital role in financial reporting, lending decisions, and performance measurement of real estate assets (Fuerst & McAllister, 2011c). The inability to properly appraise and value a property's overall sustainability performance is seen as one of the main drivers of the vicious Circle of Blame (RICS, 2008). Efforts to stimulate demand for sustainable, energy-efficient buildings among tenants and investors have faced challenges, as highlighted by Lützkendorf (2011). These challenges include the substantial underestimation of resource demand and environmental impacts associated with the real estate sector. There has been a significant overestimation of the additional expenditure required for the design and construction of sustainable, energy-efficient buildings. This misconception may have discouraged potential investors and developers from engaging in energy-friendly initiatives. Furthermore, the limited availability of appropriate investment options for investors has posed a barrier to the growth of sustainable real estate. Finally, the value of sustainable, energy-efficient buildings in terms of their positive impact on image and reputation has been underestimated. Recognizing the benefits of sustainability in enhancing branding and reputation can help drive demand for such buildings among tenants and investors.

In recent years, there has been a notable shift in response to the European energy crisis, with governments and stakeholders in the construction and real estate industry becoming increasingly mobilized to address the potential for mitigation and adaptation. Among professionals within the built environment, there is often the perception that sustainable, energy-efficient buildings generate added value. However, such added value is neither precisely defined nor researched comprehensively (Eichholtz et al., 2010). The exploration into energy retrofit financing is growing in numbers from both asset owners and occupier groups (Chegut et al., 2014). The notion that these assets may not warrant the extra investments due to a lack of knowledge of their benefits is a key inhibitor (S. Sayce, A. Sundberg, B. Clements, 2010). Investors and developers alike currently struggle with justifying the additional costs that *may* be incurred when investing in such green buildings. While a part of the financial returns to be made in organizing energy-saving improvements is measurable through efficient building performance, these returns are mostly enjoyed by occupants under typical lease contracts and in multi-tenant properties. For investors, the return is thus less certain and may consist of better marketability of properties and higher valuations (Kok & Jennen, 2012).

The role of retail

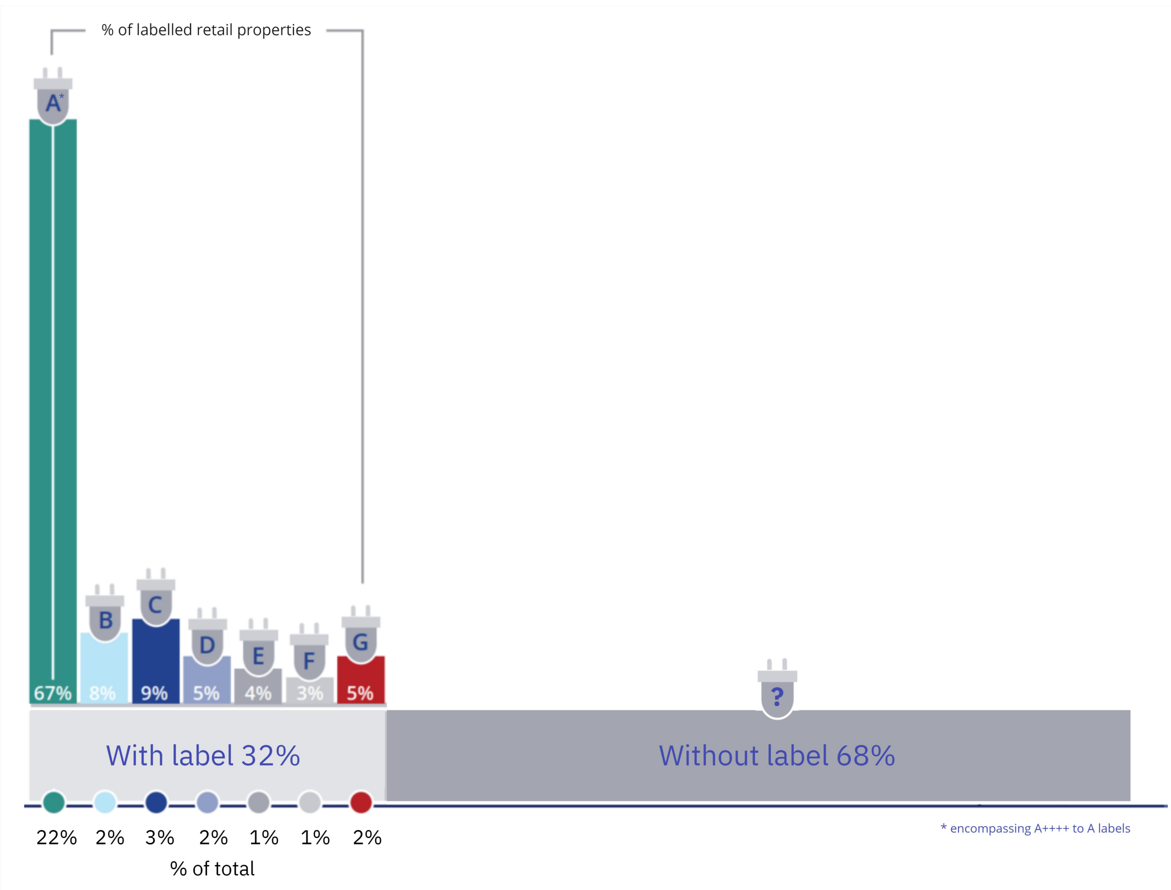

Figure 1.3: DUtch retail EPCs not yet commonplace; source: author, adapted from Colliers (2021).

The commercial property sector covers a broad and heterogeneous range of properties and business activities, including but not limited to retail, office, and industrial properties. Within the EU, commercial retail properties cover the highest floor surface area outside of residential properties, at 28 percent. The retail sector also consumes the highest share of energy outside of residential properties, accounting for 28 percent of total energy consumption (Helgesen & Task, 2014). In spite of this, no Dutch explicit legislation has been announced for retail outlets even though the sector presents a significant opportunity for energy savings and efficiency improvements.

The aforementioned lack of research into the retail sector strongly correlates with governmental policies, which have primarily focused on the residential and office sectors while overlooking the retail sector. In order for government bodies to effectively shape this crucial sector through the introduction of new regulations, it is imperative to address the considerable knowledge gap that currently exists. Market forces, such as the ongoing digitization of the retail sector underscore the mounting pressure faced by investors and retailers to enhance the appeal of the physical retail experience (KPMG, 2020). One potential solution lies in reaping intangible benefits such as brand image, as well as the tangible cost-savings that can be achieved through energy retrofits of these retail properties. All these factors collectively serve as driving forces behind the selection of the retail sector as the focal point of this research paper.

Figure 1.3 depicts the present-day EPC adoption in Dutch retail. Of the existing 100,000+ retail properties in the Netherlands, only 26 percent currently comply with an energy label of C or above (Colliers, 2021). However, a remarkable 68 percent of retail properties are not labeled, highlighting the colossal challenge that lies ahead. Collectively, these properties comprise a total area of 27 million m^2, comparable to 4,000 soccer pitches. Colliers (2021) conducted a study based on data from the Energy Research Center of the Netherlands and found that if energy labels were to be requested for all non-labeled retail properties, it is estimated that less than a quarter of these properties would achieve an energy label of C or higher. In contrast, around 50 percent of office properties would meet the same requirements. Enhancing the energy performance of retail buildings through investments in energy retrofits and regulatory changes can significantly contribute to sustainable development goals and reduce energy consumption in the retail sector.

1.2.1. Open questions in theory

From a research perspective, the current empirical studies present a mixed picture: while some studies have found evidence of price premiums linked to enhanced building energy efficiency, others have reported less conclusive findings. Nonetheless, there has been little prior research on the retail sector in relation to the value of energy performance, with even less research conducted within Europe (Dalton & Fuerst, 2018). A literature review investigating the tangible benefits to can be found in the following chapter. However, a common thread across existing research is the acknowledgment of challenges related to data availability, accessibility, and quality (McCord et al., 2020). Notably, the locational dynamics of energy performance represent an under-researched aspect in the existing literature (Bloom et al., 2011). In a geostatistical context, incorporating enhanced spatial parameters aims to improve the accurate representation of geographically diverse market structures at the neighborhood or sub-market level. This holds particular significance when considering retail prices and their spatial dependence (Rosiers et al., 2005). The economic rationale behind analyzing the spatial composition and value effects of EPCs is rooted in understanding the market adoption and uptake dynamics. It aims to determine whether properties with higher energy performance exhibit a price premium when aggregated in established and valuable neighborhoods, or if the positive/negative aspects of location influence EPC value determination. Additionally, it investigates the presence of spatial clustering and whether it is driven by property value, energy performance, or both. These dimensions are crucial for identifying potential price premiums or capitalization effects at the local level, providing valuable insights for targeted policy interventions.

The focus of this research is therefore to offer systematic insight into the effect of sustainability - namely energy efficiency - on the realized rental and capital prices of the European retail market, using the Netherlands as a case study. Consistent with prior research, this study employs a set of hedonic models to investigate the significance of EPCs and their association with location and how this impacts upon the value composition of retail properties.

1.3. Relevance

This research aims to understand the accelerators of the energy transition and stimulate investments in energy efficiency retrofits by providing insights into the financial effects of energy efficiency on the Dutch retail sector. The societal relevance of this research is established through its support of different real estate investment vehicles and policymakers alike, to combating energy consumption - a highly putative topic that has been exacerbated by the current energy crisis in Europe. Moreover, this report addresses corporate real estate sustainability management (CRESM) at various levels, including the corporate level, the portfolio level, and the individual building level. This focus is driven by the specific characteristics and considerations associated with the operational phase of real estate. The urgency to reduce the energy consumption of existing building stock along with the transition to renewable energy sources can be set higher on the agenda once the economic value of energy efficiency is better understood since it currently forms an important barrier to the inflow of capital. This research speaks to the income, value, and risk of retail properties by providing financial incentives to future-proof the existing building stock - ultimately reducing the environmental impacts of energy consumption.

From a policy perspective, the union of energy efficiency regulations in retail real estate not only contributes to economic benefits but also aligns with enhancing environmental stewardship. These outcomes are pivotal in addressing energy consumption concerns in the built environment, serving as a powerful driver for shaping policies that accelerate the energy transition. By gaining insights into the business case for energy efficiency new policies, tax breaks, grants, and loan programs can be introduced to facilitate the widespread adoption of energy-efficient practices (RVO, 2020). It can also encourage the development and adoption of energy-efficient technologies and operational strategies. This fosters a competitive ecosystem that drives continuous improvement and spurs the deployment of sustainable solutions across the retail real estate sector.

Research-driven policies and programs have played a pivotal role in fostering energy efficiency in the residential sector of the Netherlands (DGBC, 2023). For instance, academic research of similar nature has served as a foundation for the development of financial initiatives like the Stimuleringsregeling Energieprestatie Huursector (SEEH) and the Sustainable Energy Loan (Duurzaamheidslening). These programs were designed to support residents in implementing energy-saving measures. Furthermore, energy efficiency targets, such as the ”Label C Obligations”, have been extended to rental residential properties as a means to expedite energy efficiency retrofits (van Kuijeren, 2022). These targets, which require all rental residential buildings to attain a minimum energy label of C by 2023, reflect the influence of analogous academic research and its recommendations (Cushman & Wakefields, 2019). By incorporating insights derived from comparable academic research, new policies, and initiatives can demonstrate a commitment to evidence-based decision-making and the utilization of scientific knowledge to drive energy transition efforts in more building sectors (RVO, 2019).

The field of green building economics has witnessed substantial growth in academic research (Robinson, 2015), but there remains a significant gap in knowledge regarding the impact of energy certification in the retail market. Given the relative scarcity of research in this specific area, particularly within the broader European context (Op't Veld & Vlasveld, 2013), the current study aims to address this gap by offering preliminary evidence derived from the Dutch retail market, thus making a notable contribution to the existing literature. The findings from this study provide one of the very first academic insights into the relationship between EPCs, geospatial evaluations, market dynamics, and financial performance in the Dutch retail sector. Additionally, this study aims to offer valuable insights for policymakers, industry practitioners, and researchers, promoting informed decision-making, sustainable business practices, and advancing the energy transition within the retail sector. Industrial Ecology emphasizes the importance of informed policy decisions for achieving sustainable outcomes. An energy premium can inform policymakers about the economic benefits of energy certification for retail properties, encouraging the development and implementation of effective policies to promote energy efficiency and sustainability in the retail sector.

The existence of such an energy premium also dispels any misconceptions that green buildings are costly and do not yield a favorable return on investment. This concept of eco-efficiency, which aims to achieve more with less environmental burden, is well-aligned with energy premiums, revealing that energy efficiency and profitability can go hand-in-hand. Otherwise, the indication of scarcity in the market can signal to developers the demand for sustainable buildings from the Vicious Circle of Blame. In the new age of economic activities where transparency is the zeitgeist, this research hopes to mobilize responsible investments into energy-efficient buildings and shift the paradigm from merely managing downside risks to benefiting stakeholders and improving capital efficiency.

1.4. Scope, dissemination, and audiences

By examining the effects of energy certification on retail properties in the Netherlands, this research aims to shed light on the economic implications and outcomes associated with energy-efficient retail buildings. These findings have significant implications for all stakeholders involved in the Vicious Circle of Blame depicted in Figure 1.2. Valuation professionals should take note of the undervaluation of sustainability features, which can serve as a catalyst for increased market adoption of energy retrofits. Regulatory measures have proven to be influential drivers for investors, property owners, and occupants to invest in energy efficiency, underscoring the importance of these findings in shaping effective policies and practices.

1.4.1. Main research question and sub-questions

This research will examine rental and sales transactions spanning the period from 2015 to 2021, encompassing notable events such as the 2020 COVID-19 crisis and the very early stages of the energy crisis in Europe. For a paradigm driven by consumer choice and consumers' willingness to pay, the main research question to be answered is:

how big is the *energy premium* in the retail spaces, if it exists, and what are people paying for it within the Netherlands?

To answer the main research question, the following sub-research questions are posed:

1. What are the sustainable value drivers affecting Dutch retail markets?
2. What are the determinants for Dutch retail real estate?
3. How does the energy premium in the retail spaces influence rent value within Dutch markets?
4. How does the energy premium in the retail spaces influence sale value within Dutch markets?

The remainder of this paper is organized as follows: Chapter 2 provides the theoretical underpinnings for understanding the retail real estate market, its sustainable value drivers, and their economic characteristics. The following chapter presents an in-depth examination of the methodologies and data sources employed to assess the energy efficiency of retail buildings in the Netherlands. A descriptive analysis of the utilized datasets will be conducted, providing valuable insights into the fundamental characteristics, underlying patterns, and prevailing trends within the data. This analysis serves to establish a solid foundation for subsequent modeling endeavors and facilitates an initial understanding of the energy efficiency landscape within Dutch retail. Chapter 4 presents new evidence regarding the rental and capital returns associated with investments in energy-efficient retail buildings. Chapter 5 is a brief conclusion with implications for practice, policy, and future research.

2

Theoretical Underpinning

Sustainable value drivers will first, be analyzed in relation to regulatory developments on the European, and Dutch national level. Then, the role of EPCs will be evaluated against the intangible and tangible benefits in the form of a literature review of past hedonic studies on the effects of sustainability. Since a majority of the body of literature presides in the US, and UK, only commercial properties will be included for these regions, whereas a comprehensive review of residential and commercial properties will be assessed for past studies conducted in the Netherlands. Only literature published from 2007 onward has been included for temporal relevance.

Data availability and information regarding control variables play a crucial role, similar to existing hedonic studies. Therefore, a literature review is conducted to identify these key control variables that explore both spatial and non-spatial determinants of retail-specific transaction prices. An analysis of how real estate markets are situated within the broader capital market will help further inform the selection of appropriate control variables. This process ensures a comprehensive approach to model selection and enhances the validity of the findings. The 4-quadrant model of DiPasquale et al. (1992) is used to provide the conceptual framework for how property markets, asset markets, and construction markets interface with the effects of macro-economic factors. This Chapter concludes with the presentation of a conceptual framework that integrates the aforementioned theories, serving as the foundation for this study.

2.1. Sustainable value drivers

In 1972, the seminal scientific forecast Limits to Growth, (1972) shed light on the imminent and adverse consequences of the prevailing system of production and consumption, challenging conventional wisdom. The term ’sustainable’ has many connotations where the best-case scenario yields a complex answer and the worst-case scenario yields an ambiguous one. When applied through the lens of energy consumption, the Paris Agreement has garnered support from 196 parties worldwide, aiming to curtail carbon emissions and restrict the global temperature rise to well below 2°C. This commitment signifies a collective effort to achieve climate neutrality by the mid-century. Under the Paris Agreement, each participating country is required to submit a national action plan and regularly enhance their goals every five years (United Nations Environment Programme, 2017). The UN has also recommended an active tax policy for their Parties, making energy-efficient properties, more attractive.

2.1.1. Regulatory instruments

Market transformation approaches, including labeling schemes, aim to shift entire markets towards greater energy efficiency. This approach integrates policies and strategies to ensure more energy efficiency and requires a combination of policy instruments at different levels of governance. It involves providing information to consumers, offering rewards and incentives for innovation, and implementing minimum performance standards (Fawcett & Boardman, 2009; Fawcett & Killip, 2014). To maximize effectiveness, a strategic framework combines various instruments, considering both EU-level and national-level policies which will be examined below. Labeling, whether for appliances, equipment, vehicles, or buildings, is a valuable component of this framework - driving innovation and improving energy performance (Hinnells et al., 2008).

European Union

Table 2.1: EU Clean Energy Package, source: author, adapted from BPIE (2022).

EPBD	EED	RED	GR
2002, 2010 recast, 2018 amendment	2012, 2018 revision	2009, 2018 revision	2018
Legislation to decarbonize the EU building sector by 2050, promoting energy efficiency, and improving energy performance labeling	Setting the legal framework to improve energy efficiency; energy savings obligation beyond 2020 (Article. 7)	Renewable energy policy: establishing targets and measures to increase the share of renewable energy in the EU's energy mix	Cooperative framework to enhance policy coordination, ensure transparency and accountability, and strengthen the monitoring and reporting

At the EU level, a range of policies and initiatives have been developed to address energy-related challenges - one significant framework is the 'Clean Energy Package', established in 2018 which aims to ensure secure, sustainable, competitive, and affordable energy for all EU citizens. This strategy encompasses eight individual legislation papers, among which the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED), the Renewable Energy Directive (RED), and the Governance Regulation (GR) hold particular importance (BPIE, 2022). Table 2.1 depicts a general overview of these four main pieces of legislation. Alongside the Clean Energy Package, the European Commission introduced the European Green Deal in 2019 as a strategic plan to fulfill the objectives outlined in the Paris Agreement. The European Green Deal set ambitious targets, including a minimum of 55 percent reduction in greenhouse gas emissions from 1990 levels, a 32 percent share for renewable energy, and a 32.5 percent improvement in energy efficiency across sectors by 2030. The ultimate goal is to achieve net-zero greenhouse gas emissions by 2050. Given that buildings in the EU account for around 40 percent of total energy consumption and 36 percent of GHG emissions, the building sector plays a significant role in the attainment of sustainability goals for 2030 and 2050. Implementing energy retrofit measures in these buildings has the potential to result in a substantial reduction of 5-6 percent in the EU's energy consumption and a 5 percent decrease in carbon emissions (European Commission, 2020). It is important to note that the average retrofit rate for the existing building stock, to date, is less than 1 percent per year.

The Netherlands

The National Climate Agreement was born out of the Netherlands in efforts to integrate the Paris Agreement with EU Commission goals (Government of the Netherlands, 2019). Specific goals were set for the built environment for 2030 and 2050, which is currently responsible for 30 percent of total GHG emissions in the Netherlands (Colliers, 2021). Overarching goals include a total reduction of national GHG emissions by 2030, compared to 1990 levels, and an increased target of 55 percent, raised from the European target of 40 percent. This will be governed through regular assessment and evaluation of the progress made in achieving energy and climate targets. The monitoring process will rely on national energy and climate status reports, which provide comprehensive insights into the current state of affairs and trends in the energy sector. These reports will also include future forecasting, enabling policymakers to anticipate potential challenges and opportunities and adjust strategies accordingly. In order to tackle the significant portion of energy consumption in the Netherlands, a new accounting methodology has been developed to classify energy labels. This approach aims to address the 40 percent of total energy consumption in the country and a more detailed explanation of this approach will be provided in the subsequent section.

Dutch vision for the built environment 2030:

- 49 percent reduction in GHG emissions; 3.4MT GHG emission reduction, of which 1MT will be related to non-residential buildings and the remaining 2.4MT to be achieved through the renovation of 1.5 million residential homes;
- Attain a rhythm of 200,000 home renovations per year;
- District-level heating and renovation projects development.

Dutch vision for the built environment 2050:

- 95 percent reduction in GHG emissions; 7.6MT GHG emission reduction;
- Energy-retrofit of 1 million non-residential buildings for energy efficiency;
- All residential homes to be CO_2-neutral;

In pursuit of the 2030 national targets, policymakers have initiated a district-oriented approach, led by municipalities, which prioritizes residential homes given their substantial representation in the Dutch building stock (Economidou et al., 2011). The primary objective of this approach is to facilitate energy-related retrofits within the residential sector. To support and incentivize homeowners in undertaking such retrofits, a range of national subsidies and incentives are currently offered. These include the Energy Saving Subsidy (SEEH), the Sustainable Energy Production Incentive Scheme (SDE++), and the Green Loan.

To comply with the 2010 EPBD recast, the Netherlands has enforced *the Energy Agreement for Sustainable Growth* stipulating that all buildings, regardless of their type, must possess an energy label when being bought, sold, or leased. Furthermore, in line with the 2012 Building Decree, the commercial office sector is subject to additional regulations to accelerate the energy transition. As of January 1st, 2023, commercial office buildings are required to achieve a minimum energy label of C for transactions. Failure to comply with this requirement may result in the risk of closure, emphasizing the significance of energy efficiency improvements in this sector (van Kuijeren, 2022). While specific regulations targeting the retail sector are currently absent, it is important to note that energy savings obligations and other related measures are anticipated in the near future. These forthcoming regulations will play a crucial role in driving energy efficiency and encouraging energy-saving practices within the retail sector.

Dutch Green Building Council (DGBC)

The DGBC actively engages in policy discussions as a national civil society organization committed to rapidly making the built environment future-proof (DGBC, 2023). They provide expertise and insights on sustainable building regulations, certifications, and best practices. In collaboration with the retail sector, the DGBC has established energy consumption targets per square meter for retail outlets to meet the Dutch vision for the built environment 2050. For retail properties without refrigeration systems, the target for 2050 is to achieve a maximum annual consumption of 80 kWh per m^2 with primary fossil energy usage of 54 kWh per m^2. To put this into perspective, it is slightly lower than the annual energy consumption of an energy-efficient washing machine; compared to office buildings, the maximum annual primary fossil energy usage allowance is set at 36 kWh per m^2. Currently as reported by Statistics Netherlands, these properties have an average consumption of 170 kWh per m^2, indicating the need for a reduction of nearly 50 percent to meet the target.

Outlets with refrigeration systems face an even greater challenge, as they must strive to reach a target of 150 kWh per m^2. This represents a 60 percent reduction compared to their current consumption level at 350 kWh per m^2. Despite these promising sustainability initiatives in the retail sector, there is currently minimal regulatory pressure to take meaningful action. This is evident in the current state of the retail stock, which lags behind in terms of sustainability. To accelerate sustainability efforts in the retail sector, government intervention is necessary, similar to what has been implemented in the office market requiring all office buildings to at least have energy label C by 2023. While the extent of enforcement remains to be seen, this requirement has started to create movement in the office market. Introducing a similar measure for the retail market would provide the necessary catalyst to boost sustainability efforts and bring the sector closer to meeting the goals of the Paris Agreement.

2.1.2. Energy Performance Certification

Various national governments have established rating systems that measure the extent to which buildings comply with energy-efficiency standards. The Energy Star program, initiated by the U.S. Department of Energy and the U.S. Environmental Protection Agency in 1992, is one notable example. The EPBD is the main EU legislative instrument to promote energy efficiency in buildings, taking into account cost-effectiveness and adaptability to local climates and cultures. In addition to the compulsory EPC labeling, as of January 2006, the scope of inspections expanded to encompass boilers and air conditioning systems (European Commission et al., 2013). Despite the intentions of a swift and uniform introduction of EPCs across Europe, it is now apparent that not all member states have implemented similar policies: Andaloro et al. (2010) examined the uniformity and excellence of the EPBD and found that there are still large variations across Europe. In 2010, a recast of the EPBD brought about several important enhancements (RVO, 2020). While expanding the scope of the directive, and emphasizing the role of the public sector, the recast required the energy performance indicator of the EPC to be published during the advertising phase of a building for sale or rental, rather than solely at the time of signing a purchase or rental agreement. This aimed to promote better understanding and consideration of energy performance by prospective buyers or tenants along with strengthening the role of EPCs in the built environment.

Across Europe, EPC labels are the most common measurement for sustainability; as energy certificates become mandatory for property transactions, they are expected to generate a substantial amount of data over time. To date, more than 3.9 million energy labels have been issued within the Netherlands (RVO, 2021). The fundamental rationale behind market-based policy instruments, such as EPCs, lies in their ability to stimulate shifts in consumer behavior through the provision of accurate and standardized information (Davis et al., 2015). These energy-efficient features can subsequently be incorporated into rental or capital value. It has been observed in residential studies that the provision of energy consumption paperwork to private owners gives an effective 'nudge' to make energy-related improvements (Ayres et al., 2013; Costa & Kahn, 2010). In the same vein, energy labeling, in it of itself, is not the end goal but rather as an essential step to foster an ecosystem of innovation and change for enhanced energy performance of buildings (Hinnells, 2008).

Dutch EPC Grading

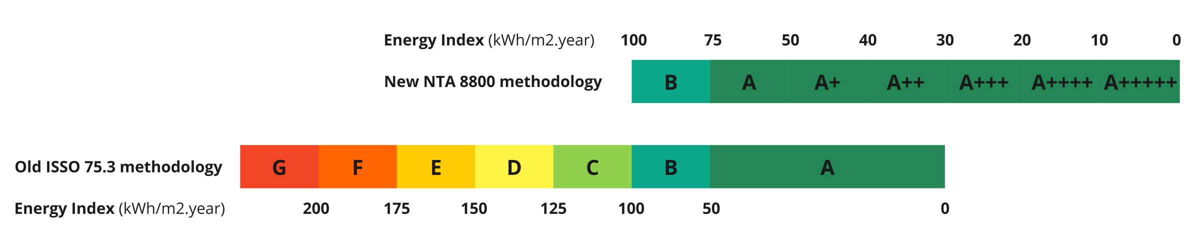

Figure 2.1: Development of non-residential EPC and EI classes; source: author, adapted from RVO (2019).

The current classification method for determining energy label grades, in the commercial sector, came into effect on January 7th, 2020 under NTA 8800 (RVO, 2019). It provides guidelines for assessing energy efficiency and the various aspects of energy performance, including but not limited to heating, cooling, ventilation, lighting, renewable energy systems, and overall energy consumption. The EPC grade of a building - representing its energy efficiency - is expressed as a dimensionless value and ranges from A+++++ to G under the new classification. Previously, labels ranged from A to G, measured by ISSO 75.3, which did not consider factors such as building envelope, heating and cooling systems, ventilation, and renewable energy sources when calculating the overall energy performance of a building. Figure 2.1 illustrates the evolution of EPC and EI in the Netherlands for non-residential properties; while under the old ISSO 75.3 methodology, the A label was intended to encompass properties with an energy consumption of 0 kWh/m².year, in reality, achieving net-zero energy consumption was extremely rare and seldom observed. Under the new NTA 8800 methodology, calculations are based upon energy demand, primary energy use, and indoor comfort and temperatures as its three main indicators. The introduction of EPC grades A+ to A+++++ in the current classification method signifies a stricter set of requirements for achieving higher energy labels. This change also resulted in the downgrading of certain properties when they undergo later transactions.

The Energy Index (EI) was introduced alongside EPCs as a part of the initial implementation of the

EPBD in the Netherlands. It is expressed as a numerical indicator, correlating to an EPC grade where lower EI values indicate higher energy efficiency. The relationship between the EI and its corresponding EPC label was not linear under the old methodology, however, the inclusion of the higher energy classes establishes a linear relationship between the new EPC labels and their corresponding EI. The specific EI ranges corresponding to different EPCs are depicted in Table 2.2.

Table 2.2: EPC categories and the corresponding energy indices under NTA 8800; adapted from RVO (2019).

Energy Performance Label	Category
A+++++	Energy Index $\leq$ 10 kWh/m².year
A++++	10 < Energy Index $\leq$ 20 kWh/m².year
A+++	20 < Energy Index $\leq$ 30 kWh/m².year
A++	30 < Energy Index $\leq$ 40 kWh/m².year
A+	40 < Energy Index $\leq$ 50 kWh/m².year
A	50 < Energy Index $\leq$ 75 kWh/m².year
B	75 < Energy Index $\leq$ 100 kWh/m².year
C	100 < Energy Index $\leq$ 125 kWh/m².year
D	125 < Energy Index $\leq$ 150 kWh/m².year
E	150 < Energy Index $\leq$ 175 kWh/m².year
F	175 < Energy Index $\leq$ 200 kWh/m².year
G	Energy Index > 200 kWh/m².year

2.1.3. Voluntary Eco-labels

A comparative analysis is undertaken to examine the methodology and applicability of the two most prominent voluntary eco-labels - LEED and BREEAM. This review aims to provide insights into the key features and characteristics of these eco-labels, considering their adoption rates and relevance in the context of sustainable building practices. As previously mentioned, the green building landscape is dynamic and evolving, with the relative popularity and adoption of certification systems shifting over time. Their dominance are varying depending on the geographical context as well.

BREEAM

BREEAM originated in the United Kingdom in 1990 and has established itself in 86 different countries, along with a strong presence in Europe (DGBC, 2023). The assessment framework values the environmental, social, and economic sustainability performance of the real estate property throughout its entire life cycle. The building's performance is assessed based on the type of property, including constructed assets, in-use assets, and refurbished assets. The BREEAM rating system encompasses a range of performance levels, including Pass, Good, Very Good, Excellent, and Outstanding, with each level corresponding to a specific total percentage. The certification is visually represented by the number of stars on the official certificate.

The goals of the BREEAM rating system are to promote buildings with low environmental impact and encourage best environmental practices in the planning, design, construction, and operation of buildings and the wider built environment (UKGBC, n.d.). The Dutch Green Building Council (DGBC) customized the BREEAM rating system to align with Dutch regulations, resulting in BREEAM-NL. BREEAM-NL evaluates buildings across nine distinct categories: management, health and comfort, energy, transportation, water, materials, ecology and waste, waste, and land use. Every asset can score additional innovation points, similar to the accreditation process in LEED.

LEED

LEED, on the other hand, was developed by the U.S. Green Building Council in 1993 and has gained significant popularity and market penetration, particularly within North America (USGBC, n.d.). It has been widely adopted by building owners, developers, and professionals in nearly 190 countries, seeking to demonstrate their commitment to sustainable design, construction, and operation. The LEED rating system accounts for different real estate types vis-a-vis new construction to fit-outs. They range from certified (40-49 points) to silver (50-59 points), gold (60-79 points), and platinum (80+ points). LEED dubs itself a comprehensive system that takes a holistic approach, addressing various important aspects without focusing solely on individual building elements. It engages with topics such as decarbonization, electrification, equity, ESG, green finance, human health, net zero, and resilience through its diverse credit categories. These categories include location, transportation, sustainable site development, water efficiency, energy and atmosphere, and material selection and use. LEED also incorporates specific credits for promoting innovative practices and addressing local environmental priorities within the built environment. Among the critical categories covered by LEED, only operational and embodied carbon are accredited for.

Key Takeaways

Table 2.3: LEED and BREEAM-NL performance comparison; adapted from Saunders (2008).

Category	LEED	BREEAM-NL
Management	-	11%
Health	16%	19%
Energy	33%	20%
Transport	16%	6%
Water	11%	7%
Materials	13%	13%
Waste	-	6%
Land-use	10%	8%
Pollution	-	10%
Integrative process	1%	-
Total	100%	100%

The concept of a *green building* is gaining institutional recognition, resulting in eco-labels acquiring a quasi-compulsory status, as described by Fuerst and McAllister (2011a; 2011b). A comparative analysis of the category allocations between BREEAM and LEED was conducted by Saunders,(2008), and the findings are presented in Table 2.3. However, it is exactly the assignment of such weightings to environmental impacts that remains a subject of ongoing debate, particularly regarding the theoretical energy efficiency of building systems and structures versus their actual efficiency. Lee (2013) reveals large differences between actual and theoretical measures in efficiencies, mainly due to intervening behavioral factors which are not taken into account in both LEED and BREEAM eco-certification schemes. From a policy point of view, the effectiveness of voluntary schemes, demonstration projects, and pilots in driving market transformation is limited, as they often fail to stimulate widespread adoption. To truly catalyze transformation, mandatory energy performance standards play a crucial role along with the process of industry engagement (European Commission et al., 2013).

Nevertheless, voluntary eco-labels occupy a prominent position in scholarly investigations concerning sustainable buildings, alongside energy efficiency. The primary objective of this study is to exclusively evaluate the presence of an energy premium, with discussions on its tangible benefits in the subsequent section below.

2.1.4. Tangible benefits - energy performance labeling and property values

There are multiple perspectives regarding the value of property (Sayce et al., 2010). The focus of this study revolves around the exchange value of property, which is determined through rentals and sales transactions. Research investigating the value of energy performance in the residential sector has been in existence since the 1980s in the United States with the pioneering study by Halvorsen and Pollakowski (1981a) in Seattle, finding a marginal pricing effect between different heating types. Subsequent studies by Gilmer (1989) and Dinan and Miranowski (1989) followed suit, finding positive impacts of energy labels and energy retrofits. Since then, the introduction of mandatory energy labeling in the different sectors of real estate has sparked increased research activity in this area. Based on empirical evidence, a discernible energy premium is evident within the residential sector. This can be attributed to the early targeting of the residential sector in policy-making decisions or the closer impact of energy prices on households. However, when considering all sectors, the emerging body of studies presents a mixed picture. A substantial number of studies have identified energy premiums linked to enhanced energy efficiency and labeling, while others have found tempered results indicating varying results across different contexts and analyses. The common thread in existing research, however, is the lament unavailability, inaccessibility, and deficiencies of data which leaves room for omitted variable bias and potential endogenous challenges (McCord et al., 2020).

Highlighting the well-recognized issue of capturing good quality data within real estate, literature on green premiums is predominately focused on the U.S. market, particularly on residential properties. Moreover, much of the eco-certification within the body of literature is not applicable to the Netherlands, such as the LEED program (Chegut et al., 2014; Kok & Jennen, 2012). While the body of work is too large to review meticulously, key insights gained into USA and EU commercial markets are examined, along with a more comprehensive examination of studies focused specifically on the Netherlands.

USA

The entirety of the literature around energy and green premiums on American commercial properties focuses on office buildings, with a gaping knowledge gap in the retail sector. All empirical investigations conducted on the office sector in the United States have consistently revealed diverse magnitudes of positive premiums on rental rates, property values, and/or occupancy rates associated with energy-efficient buildings (Das & Wiley, 2014; Eichholtz et al., 2010; Fuerst & Van de Wetering, 2015; Fuerst et al., 2013; Miller et al., 2008; Robinson, 2015; Wiley et al., 2010). Data selection, availability, and omitted variables are acknowledged to be the main contributors to the differences in the results, despite the US exhibiting the highest quality of data in terms of its sample size and number of variables (Dalton & Fuerst, 2018; Op't Veld & Vlasveld, 2013). The earlier studies found large differences in sales prices (see McAllister, 2009) and the groups of energy efficient and energy inefficient properties exhibit large differences in age, size, and/ or vacancy levels.

Eichholtz et al. (2010) conducted one of the first comprehensive studies, employing an extensive set of control variables tailored to the commercial sector to ensure robustness in the analysis. These variables accounted for the increase in service sector employment within the area. Additionally, they considered specific determinants for office business activity, such as the number of stories the building has, and included dummy variables for amenities around the commercial property. A key distinction of their research is the incorporation of location controls considering a spatial range of 0.2 square kilometers, offering a more refined analysis compared to broader city or sub-market levels. This approach, which is rarely observed in hedonic research of this nature, allows for a more nuanced understanding of the spatial dynamics and localized effects of green attributes on property values. Even after accounting for these meticulous control variables, the sustainability premium observed in their study retained its statistical significance at a high level.

Europe

Within Europe, Chegut, Eichholtz and Kok (2011) pioneered the first study into green premiums, relating rental and capital values of UK offices to BREEAM certifications over the 2000-2009 period. The literature on green premiums in Europe primarily revolves around the UK. In their data collection efforts, they obtained a complete rental sample of 1,171 lease transactions, including 67 BREEAM-certified leases, and a sales transaction sample of 2,023 observations, including 70 BREEAM-certified transactions, which were subsequently utilized in their hedonic model. A 21 percent rental and a 26 percent sales premium were observed with variables controlling for location (at the ZIP-code level), property area size, age, storage, amenities, and dummy variables for renovations.

The European Commission (2013) also published a wide-scale report, studying several European city markets regarding the effects of EPC labeling on sales and rent transactions. The limited availability of data emerged as a notable finding, highlighting its implications for impeding policy research, monitoring, and evaluation efforts. Consequently, all the examined case studies neglected to adequately control for location characteristics, opening it up to critique as the scope lacked comprehensive and consistent control variables across different countries. Nonetheless, the report included coverage of urban and rural properties, warm and cold climates, and includes data from France (Marseille and Lille), Ireland, Belgium (Flanders, Wallonia, and Brussels-Capital regions), and the UK (Oxford and region), with a smaller data set for Austria (Vienna). The findings consistently demonstrated a premium effect in each case study.

Fuerst and McAllister (2011c) examined the impacts of EPCs on London's retail, office, and industrial real estate properties - a first for the retail sector - where no evidence of a price premium could be observed in any of the building categorizations. For the hedonic model, a total of 293 retail transactions, 226 office transactions, and 173 industrial transactions from 2010 were utilized. Control variables included BREEAM certification as an added *green* effect on top of the EPC labels along with vacancy rates, weighted credit risk scores, rent-able area size, region dummies, and building segment dummies. The authors offered an explanation for the absence of statistical significance, suggesting that the small sample size of 708 observations and the fact that only one property in their dataset achieved an EPC A rating, might have contributed to this outcome. This finding further underscores the existing challenges related to data deficiencies, particularly within the retail sector.

The Netherlands

The study conducted by Brounen and Kok (2011) holds significant importance as one of the seminal studies in Europe that examined the economic implications of EPC labels, using 177,000 transactions in the Netherlands as a case study. Their research examined two fundamental aspects of the dissemination of EPC labels and their effects in the Dutch residential market for 2008–2009. Firstly, the adoption of EPCs within the Dutch housing market is based on economic and political behavior (due to geographic variation), and secondly, market signaling along with the capitalization effects of energy labeling. Neighborhoods with a particular property type that are densely situated, housing low-income residents who are politically aligned towards climate issues exhibited a propensity towards adopting EPC labeling. Neighborhood control variables included housing density, time-on-market, and monthly household income. The energy premium they observed varied from 10 percent for A-rated properties when the dwelling was sold, to a discounting effect of 5 percent for G-rated properties, when benchmarked against D-rated properties.

In more recent studies conducted within the Netherlands, Chegut et al. (2016) analyzed 17,835 sale transactions of EPC labels and their effects on the Dutch affordable housing market over the period 2008-2013. A price premium of 2.0-6.3 percent was found when compared to otherwise similar homes with low energy efficiency. Murphy (2014) took a different approach to determining a price effect for energy efficiency and drew on data from ex-ante and ex-post assessments of the EPC label. A survey was conducted to investigate the influence of EPCs on Dutch private dwelling purchasers. It was found that EPCs did not heavily sway homeowners' buying decisions, especially for pre-purchase.

To date, only one study exists on energy efficiency and the Dutch retail market. Op't Veld and Vlasveld (2013) looked into the EPC effects on the investment performance of a retail portfolio consisting of merely 128 properties. It was found that energy-efficient retail properties initially had a higher income return of 0.53 percent, but after controlling for various factors such as center size, catchment area, and adjusted property size, the energy premium become insignificant. Counter-intuitively, the analysis revealed that energy-efficient retail properties exhibit significantly lower rent and sale values at a 99 percent confidence level - contradicting most findings in the office and residential sectors. Additionally, another unexpected outcome emerged, indicating that energy-efficient properties have a higher vacancy rate compared to energy-inefficient properties, at a 95 percent confidence level. The authors attributed these contradictions to the importance of traditional retail location theory factors, given the vastly differing descriptive statistics of the energy-efficient and energy-inefficient properties. It was found that non-green properties in the dataset were more predominant in larger city centers, roughly 25 years older than the green properties, and on average, occupied smaller retail units. Notably, within the context of the Netherlands, large city centers primarily encompass renowned historical high streets, which are known to command higher rents and hold significant value for consumers. This finding underscores the influence of location and historical significance on the composition of green and non-green properties in retail markets. The significant difference in rent, sale value, and income returns are therefore less influenced by the energy label but rather catchment properties in line with the retail theories by Alonso (1964) and Christaller (1980). Furthermore, the data sample used in this study, while is of high quality, is very limited and does not contain sufficient transaction numbers to be conclusive for the entirety of the Netherlands. This once again, highlights the secular issue of data for all hedonic modelling of this nature.

Key Takeaways

By and large, a majority of existing literature points to energy-efficient properties being rewarded with an energy premium, yet the study with the same sectoral classification within the Netherlands proves otherwise. All literature point to how the research is contingent on the granularity of the data and the hardships of obtaining such data. Aroul and Rodriguez (2017) raise a compelling argument regarding the generalizability of the findings when analyzing energy performance since attitudes (along with their price premiums) differ vastly with regard to green amenities across different markets. This suggests that the effects observed in the office and residential markets may not apply to the retail sector and that these energy premiums, very much remain a behavioral issue. This is further exacerbated in the retail sector since it is a very customer-driven classification that influences the shopping experience and spending behavior.

And while most of the literature on energy premiums is conducted in the US and the UK, the Netherlands outperforms the US and UK in ESG ratings, indicating a more attractive ecosystem for sustainable investments (Lopez-de-Silanes et al., 2020). This paper adds to the literature base in the Netherlands, pertinent for institutional investors when bench-marked against US and UK markets. It has also been observed within the literature that location variables for providing geographical characterization on the role of energy performance in a wider market context are vastly missing, partially due to barriers in data (European Commission et al., 2013). Location and catchment play a crucial role within the retail sector, this paper is positioned to determine the extent to which energy labeling is associated with location and how this impacts the pricing effect in Dutch retail.

2.2. Real estate market determinants

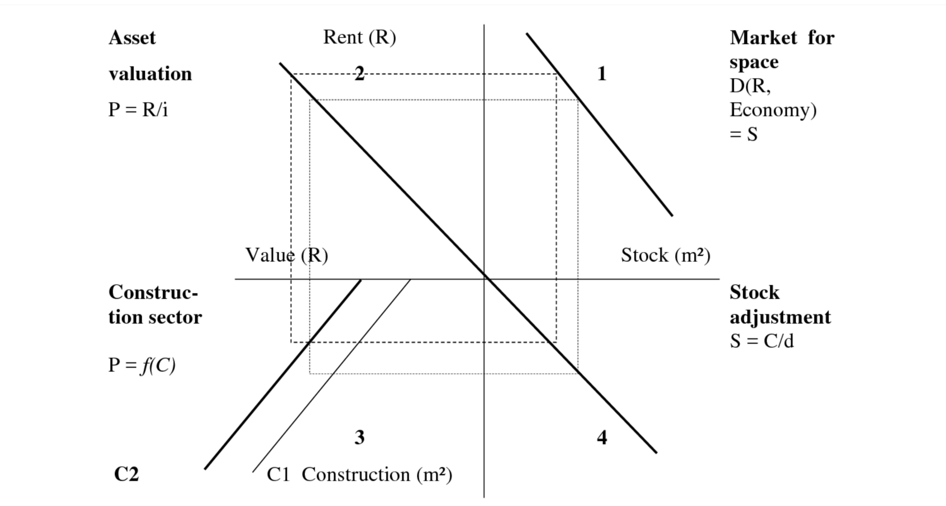

Figure 2.2: Four quadrant model, adapted from DiPasquale & Wheaton (1992).

Real estate markets are directly related to the national economy, wherein the performance and returns of the retail real estate market are subject to the influence of periods characterized by high economic growth. These periods typically witness a surge in the demand for retail space, accompanied by the expansion of consumer spending and business activities. The augmented levels of consumer confidence, disposable income, and retail sales positively impact the performance and returns of retail real estate (Neil & Webb, 1994).

Figure 2.2 illustrates the conceptual framework proposed by DiPasquale and Wheaton (1992) providing the first systematic approach to understanding the dynamics and interactions that influence real estate market outcomes; it is arguably the most advanced diagrammatic quadrant real estate model available at present (du Toit & Cloete, 2004). Although the framework is applicable to residential and commercial real estate alike, this research will only focus on the commercial side. At the core of the framework is the notion that real estate markets are characterized by spatial heterogeneity, where the primary objective is to determine *market equilibrium*. It is founded on the principles of *demand and supply modeling*, with supply reflecting the availability of space and the characteristics of the built environment, and demand representing the preferences and needs of owners and occupiers. A difference is denoted between space markets, where transactions occur, and asset markets, where property values and investment decisions are determined.

In equilibrium, real estate supply matches demand at a specific price (Quadrant 1). The price paid for, by an investor, is a function of real or imputed rent (Achour-Fischer, 1999, p. 34), which is capitalized at a suitable capitalization rate (Quadrant 2). The difference between property values and replacement cost drives new development (Quadrant 3). Even in strictly static conditions, construction is needed to maintain stock, accounting for demolition, withdrawal, or deterioration (Quadrant 4). Adjusted stock becomes the long-term supply (back to Quadrant 1) ensuring a balanced real estate market. This framework encompasses a range of stakeholders, who also play a crucial role in the Vicious Circle of Blame. DiPasquale and Wheaton also underscore the influence of broader economic factors on real estate markets, including macroeconomic conditions, interest rates, and government policies. The feedback mechanisms between the real estate market and the overall economy are stressed to highlight the potential for both positive and negative spillover effects. The role of market segmentation, whereby properties are differentiated based on various attributes such as location, quality, and intended use, emphasizes the importance of control variable selection. The following section will provide a comprehensive examination of key determinants affecting prices in the retail real estate sector, drawing on previous research and theoretical insights pertaining to property value and spatial factors.

Classification of retail properties

Quantitative research investigating the impact of spatial and non-spatial price determinants in the retail sector has made limited progress, and the application of hedonic analysis in this domain remains in its early stages. The existing literature analyzing rent determinants is predominantly centered around the residential sector, with limited research on the commercial sector. Office properties have received more attention, with the pioneering study by Vandell and Lane (1989) which investigates the value of quality design in relation to spatial and non-spatial price determinants. Hedonic models for retail property are rare if at all existent (Geltner et al., 2017) yet they display a wider range of spatial and non-spatial price determinants (Mejia & Benjamin, 2002). Take, for example, retail typologies and retail mixes - the association of rent and sale prices may heavily differ depending on these externalities (Rosiers et al., 2005).

While it may be challenging to directly generalize findings around price premiums from other sectors such as residential and offices, it is worth noting that offices and retail properties both fall under the category of commercial real estate. Consequently, certain hedonic characteristics identified in office property studies can potentially be applied to retail properties: the same cannot be said about residential real estate. By leveraging these characteristics, transaction prices in the retail sector can be filtered and analyzed. Downs and Slade (1999), Fisher et al. (Fisher et al., 2003), Munneke and Slade (Munneke

& Slade, 2001), Tu et al. (2004) and Nappi-Choulet and Maury (Nappi-Choulet Pr & Maury, 2009) apply a hedonic price model to construct price indices for offices. The explanatory variables in these studies include:

1. Office size;
2. Building size;
3. Building segment (A, B, etc.);
4. Building materials;
5. Number of stories;
6. Age of the property;
7. Renovated or renovation year;
8. Amenities;
9. Use (such as single-tenant, mixed-use, multi-tenant);
10. Green rating;
11. Financing type;
12. Leasehold or otherwise;
13. Date of sale; and
14. Location, (measured by regional dummy variables and/or distance to the central business district)

To date, there is a lack of literature specifically focused on employing hedonic price modeling to construct price indices for retail spaces. The existing body of literature investigating spatial determinants of retail prices focus on shopping centers (Hui et al., 2007; Mejia & Benjamin, 2002; Rosiers et al., 2005; Sirmans & Guidry, 1993) and retail clusters such as high-street or neighborhood centers (Hardin & Wolverton, 2001; Hardin et al., 2002; Nase et al., 2013). Sirmans and Guidry (1993) studied the determinants of retail rents for shopping centers in Louisiana during the time period 1989-1991. The authors identified four major determinant groups of shopping center rent which constitute the control variables for their weighted least squares hedonic model. These determinants were grouped by customer drawing power, center design, location characteristics, and market characteristics. Variables influencing customer drawing power are size, age, and retail typology. Center design dummy variables specified linear, mall, cluster, U-shaped, and L-shaped retail typologies. Location characteristics included district dummies and location on streets with high traffic as a proxy for footfall since direct footfall data was unattainable. Market characteristics included transaction period dummies and vacancy dummies. The findings suggest that rent levels in the retail sector are influenced by multiple factors, with variables in the ”customer drawing power” group emerging as the most crucial factor in explaining a significant portion of the variation in rent levels.

Rosiers et al. (2005) examined 1007 rental units within shopping centers in Quebec City with the aim to model the economic trade-off between spatial and non-spatial determinants of shopping center rents, while also assessing the influence of neighborhood and location attributes on the rent setting process. Control variables were grouped by size, retail typology, an Economic Potential Index (EPI), and a Center Attraction Index (CAI) to explain the relationships between endogenous and exogenous determinants. The first two groups account for endogenous attributes of the shopping centers, the variable area, and dummies for the specific type of retail activity whereas, the later two groups account for exogenous attributes. The EPI was a proxy for the sales potential of the shopping center, calculated as a percentage of the number of customers at a particular zone multiplied by the annual personal income from the same zone. The CAI uses Reilly (1929) model of retail gravitation expressed as a percentage. The findings of the study confirm the significant influence of the EPI as the main determinant of shopping center rents. However, they also highlight the complexity of the relationships between endogenous and exogenous factors that contribute to rent determination.

In a different study on Hong Kong shopping centers Hui et al. (2007), the importance of exogenous determinants is reinforced through its investigations into market positioning on rent. Control variables were grouped by physical characteristics, location of the facilities, and market position. Physical characteristics included common variables such as age, size, and number of shops in the shopping center. Vacancy dummies and efficiency ratio - the lettable area divided by the gross floor area were also included in physical characteristics variables. Location variables included dummies for different districts. Market position dummy variables specified district, estate, local center, or individual shop venue location. The study revealed that district centers have the highest average rental levels, followed by local and estate centers - in terms of the impact of individual variables on rents, the age of a retail property and its efficiency ratio exhibit negative relationships with rents, while the size and the number of shops have a positive effect on the rental levels of the facility. Be that as it may, it is crucial to note the contextual differences between Hong Kong and the Netherlands in terms of their retail landscapes. The unique characteristics of the Hong Kong market may limit the generalizability of the findings but the identified control variables are noteworthy in understanding the dynamics of how retail characteristics impacts upon the pricing effect.

To date, there is only one study that investigates spatial and non-spatial determinants of retail prices in Europe (Nase et al., 2013). The hedonic study of the Belfast City Center high-street cluster listed five groups of control variables: physical characteristics, market characteristics, time controls, spatial controls, and quality design variables. Variables influencing physical characteristics include age and area. Market characteristics include retail typology and vacancy dummies. Time controls include transaction year, lease time, and review period. Spatial controls are represented by variables such as distance to the predefined retail core, CAI (as seen in Rosiers et al., 2005), a connectivity index, a corner unit dummy, and shop-frontage-block perimeter ratio. The quality design variable measures the appropriateness of a building's design to its surrounding grade - considering architectural and urban scale attributes. The authors based this on literature and discussions with experts and qualities such as material choice of the exterior facade, facade identity, quality of the exterior material, and building condition were given a grade on a five-grade Likert scale. The findings of this study indicate that various aspects of spatial design, including connectivity, frontage continuity, location, and retail typology, contribute to the overall value of real estate. These findings complement existing research on retail-specific value determinants that highlight the significant influence of factors such as locale, tenant typology, and properties falling in Segment A streetscapes.

Key Takeaways

The literature review conducted in this section identified a range of control variables that have been consistently recognized as significant determinants of retail prices in previous real estate research. These few studies have contributed valuable insights into the underlying mechanisms influencing retail values but were bound to the unique data employed which notably focused on shopping centers. Still, the quantitative approach to measuring spatial and non-spatial is still largely unexplored due to the unavailability, inaccessibility, and/or deficiencies in retail data. This heightens misspecification issues and the risk of omitted variable bias. According to Fuerst and Van de Wetering (2015), these omissions may be misattributed as a price effect for another variable. The inverse also holds true, where the inclusion of highly correlated variables that are incorrectly accounted for can also muddy the pricing effect - true for any hedonic pricing model. Nonetheless, all the studies echo the same sentiment and dub this area of research as one that requires further attention. As for theoretical underpinnings, most studies are implicitly grounded in agglomeration and central place theory to explain the impacts of different variables on the levels of rent achieved (Ke & Wang, 2016). In this way, all research points to the age-old adage defining the three most important determinants of retail property valuation: location, location, location.

2.3. Conceptual Framework

Drawing upon the comprehensive literature review presented in the previous sections, a conceptual model is formulated to guide the subsequent analysis and research. Hence, four major descriptor series have been identified that influence the rental and sale prices of retail properties from the literature. These determinant groups - descriptor series - are geographic regions, retail positioning, physical characteristics, and transaction type.

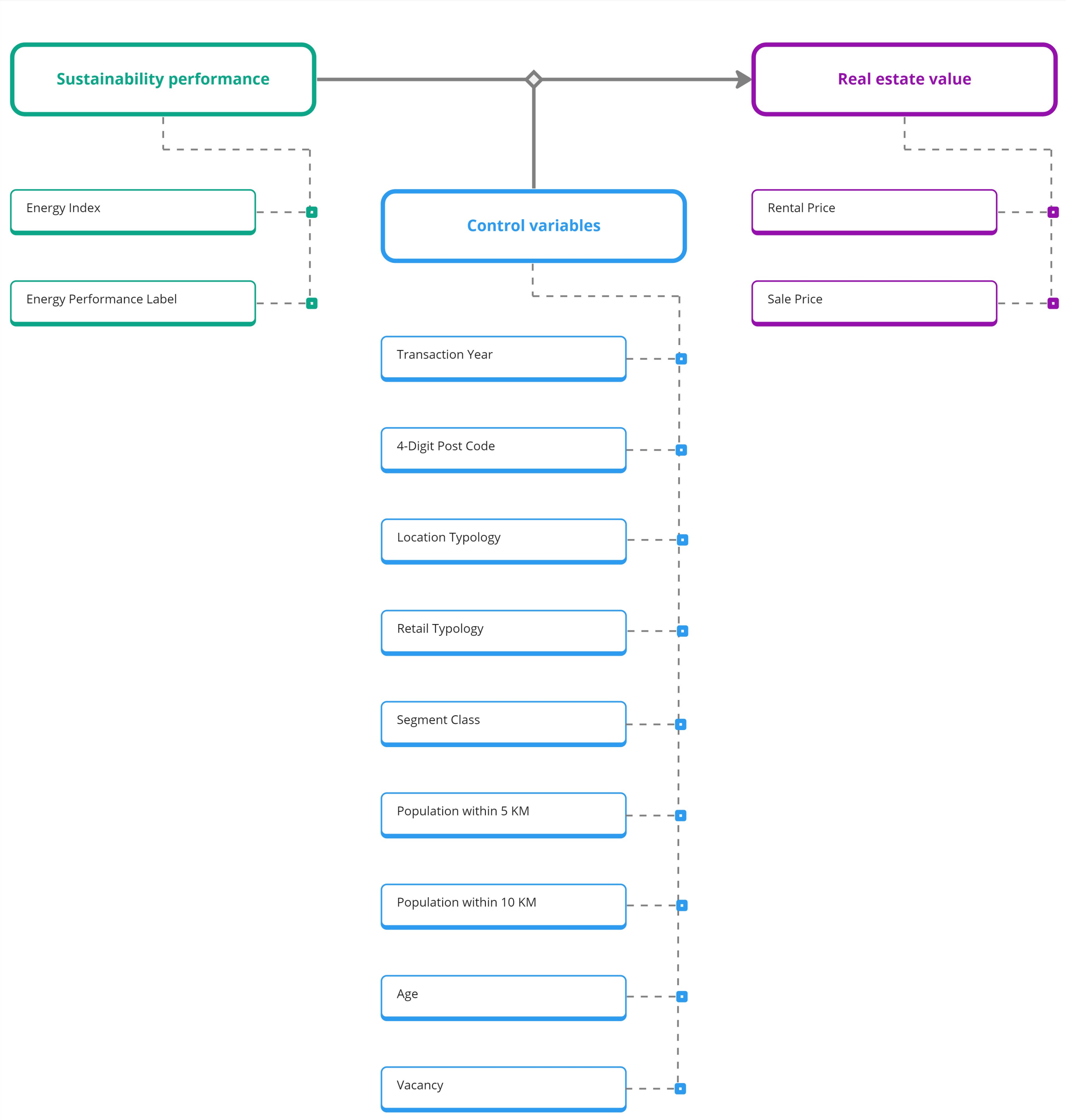

Figure 2.3: Conceptual framework; source: author.

2.4. Hypotheses

The primary objective of this research is to investigate the correlation between energy performance certification and historical rents and sales in the retail sector. The central research question aims to determine the magnitude of the *energy premium* in retail spaces if such a premium exists and to understand the monetary value associated with it in the context of the Netherlands. Drawing upon existing literature on energy premiums, the study formulates these hypotheses that will be examined through the application of multiple hedonic regression analyses:

H1: A higher Energy Performance Certificate label positively correlates with a higher rental price premium.

The limited studies around retail properties all report a lack of rent premiums. However, all the studies admitted glaring data issues with insufficient sample sizes and a lack of representative data: in one study, the retail dataset contained only one observation with Label A or above, resulting in a substantial bias in the analysis (Fuerst & McAllister, 2011c). Despite the varying results in the current literature, the rental advantages of energy-efficient retail properties within the Netherlands are multifaceted. Drawing insights from other sectors and the Dutch retail landscape, these benefits include higher occupancy rates (Sayce et al., 2010) and lower operational costs (Ahn et al., 2013), directly benefiting tenants through savings. For investors, the appeal lies in mitigating long-term risks and showcasing CSR credentials, influencing their investment decisions (Serpell et al., 2013). These advantages, paint a promising picture for a rental premium to be associated with energy-efficient retail properties in the Dutch market.

H2: A higher Energy Performance Certificate label positively correlates with a higher sale price premium

The presence of a sale premium for energy-efficient retail properties within the Netherlands has been subject to a notable dearth of empirical evidence. Nonetheless, findings from comparable sectors and the Dutch context offer valuable indicators of the potential benefits associated with energy-efficient retail properties. These advantages encompass reduced asset depreciation, leading to higher property valuation and improved liquidity—qualities that prove increasingly significant in light of the decline of physical retail spaces (Devine & Kok, 2015; Pheng Low et al., 2014; Pulselli et al., 2007). Moreover, higher EPC labels are associated with the mitigation of long-term risks, the incorporation of CSR credentials, and lower vacancy rates, as well as the cultivation of a positive image, branding, and reputation (Arif et al., 2009; Serpell et al., 2013). All these factors align with the expected price premium for retail properties, underscoring the multifaceted advantages that a higher EPC label can offer in the competitive retail market.

The anticipated distinctions in energy premiums between rental and sale transactions revolve around the stakeholders' gains from such benefits. For tenants, the key consideration is whether the savings in monthly operational costs outweigh the rental premiums associated with inhabiting an energy-efficient property. Spatially aggregated, these premiums might cluster due to factors such as property value, energy performance, or a combination of both. Hypothesizing that H1 and H2 hold true, given the substantial energy consumption of retail shops, it is logical to expect that the rental premium may surpass the sale premium. Notably, tenants benefit from energy retrofits without having to bear the upfront investment costs. Conversely, in the case of sales premiums, there is a more stable dynamic, yielding long-term capital gains in addition to short-term income gains when implementing energy retrofits. However, owners do assume the upfront investment costs associated with such energy retrofits. The balance between these factors ultimately shapes the divergence in energy premiums observed between rental and sale transactions in the retail sector.

To test these hypotheses, two separate OLS hedonic regression models will be employed. These models will include the various control variable groups identified in Figure 2.3 such as geographic regions, retail positioning, physical characteristics, and transaction type. The coefficients of the EPC label variables will be analyzed to determine their statistical significance and sign, providing insights into the presence and magnitude of rent and sale premiums associated with EPC labels. The following chapter will delve into the unique datasets employed and the methodology chosen, accompanied by a descriptive analysis.

3

Data & methodology

While there are plausible *a priori* reasons to hypothesize a positive correlation when measuring a price differential between energy-efficient and energy-inefficient properties, this chapter will present the methodology chosen to measure these financial effects along with the proprietary datasets on EPC certification and rental and sale retail transactions within the Netherlands.

Eurostat's commercial property indicators identify three primary methods for measuring transaction-based property price changes (Geltner et al., 2017): 1) the stratification approach; 2) the repeated sales method; and 3) the hedonic regression method. The hedonic regression method was chosen for its ability to measure the correlations and significance of individual rent determinants, such as EPC grade - it models the financial performance of a property as influenced by individual characteristics. In comparison, the stratification method cannot make quality-mix adjustments which may result in inefficient allocation of observations. And the repeated sales approach can only account for heuristic evidence and relies on the oversimplified assumption that the change in price between two transactions reflects the change in property value, independent of other factors (Herath & Maier, 2010). As previously mentioned, hedonic studies on retail property are still embryonic when compared to other sectors, partially due to the confidentiality associated with retail transactions (Rosiers et al., 2005).

3.1. Data Collection

The data is obtained from a combination of three different datasets representing a cross-section of the retail landscape in the Netherlands. Rental and sales transaction data from The Dutch Cooperative Association of Estate Agents and Appraisers (*De Nederlandse Coöperatieve Vereniging van Makelaars en Taxateurs*; NVM). NVM is an established association of real estate agents and appraisers in the Netherlands dating back to 1898. They encompass circa 75 percent of all recorded property transactions across the Netherlands ("NVM Expat Services", n.d.).

The initial database of 1078 retail rental records and 490 retail sales records for 2015-2021 was purged based on the removal of missing observations, erroneous data entry, and property types outside of the retail function. Data entries are compiled by real estate agents with supplemental transaction data from Vastgoedmarkt and Property NL. Attributes on hedonic characteristics, such as age, address, and transaction year are included. This is subsequently merged with the data set from Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland*; RVO) comprising of full addresses, EPC data, and size of property. An address-matching exercise was performed to align the EPC scores with the hedonic characteristics from NVM. Lastly, a retail-specific database, extracted from Locatus, was further stratified to provide information on the catchment area, retail type, tenant, and type of locale the property lies within. Locatus is a Dutch research firm that collects and constructs property-level data points on all retail and consumer-oriented service companies in the Benelux region. A final address matching exercise was performed to create a unique dataset encompassing 1015 lease properties and 478 sale properties, complete with EPC label, transaction price, size, location, and various building and retail hedonic characteristics.

3.2. Methodology

The methodological approach of this paper will be based on hedonic price theory, where data will be regressed and weighted to test H1 and H2 on the relationship between energy-efficient buildings and market transactions in the Dutch retail sector. The data analysis process consists of two main steps, all conducted using Python programming language. First, to see whether there are statistical differences between energy-efficient properties and energy-inefficient properties, the groups have been compared using a t-test for the normally distributed variables and a Mann-Whitney test for the not-normally distributed variables. A summary of the descriptive statistic for rental and sales data can be found in Table 3.1 and Table 3.2, respectively. Second, the two unique datasets have been examined with two distinct OLS regression models in both rental and sale transactions. All control variables, where appropriate, were transformed into a binary state to indicate the absence (0) or presence (1) of a categorical effect that will be expected to shift the intercept of the influencing coefficient (Walker, 1989). The remaining variables were tested for normality through a Kolmogorov-Smirnov test. On variables that were not normally distributed, a natural log transformation has been applied.

To ensure the consistency and efficiency of the model, a battery of statistical tests was employed. These included the graphical interpretation of scatter plots and histograms which can be found in Appendix B. Additionally, both datasets underwent thorough checks and corrections for potential issues such as multicollinearity, assessed through Variance Inflation Factors, heteroscedasticity, analyzed through a Breusch-Pagan test, as well as identification and handling of dependency errors and non-linear relationships that could significantly influence the gradient of the regression line. Outliers, that have a substantial impact on the estimated regression coefficients have been removed using Cook's Distance measure - a commonly employed statistical test to assess the robustness and reliability of regression models. It quantifies the change in the regression coefficients when a particular observation is removed from the dataset. Cook's Distance is calculated for each data point and provides a measure of how much the fitted values change when that observation is excluded (Cook & Beckman, 2006). Cook's Distance was utilized to identify and remove outliers in the rental and sale transaction prices and square meterage.

Both rental and sale datasets have limitations due to the lack of data, notably the absence of certain determinants related to energy-efficient features, such as operational expenditures and specific building property features. It is important to acknowledge that while these limitations exist, this dataset represents the most comprehensive and reliable information available, given the inherent challenges of accessible data collection and measurement for academic research. Despite these constraints, efforts were made to include major attribute variables that influence pricing and EPC scores. While the lack of detailed granularity in the data can impact upon the analysis of significant determinants, it may also introduce issues related to multicollinearity. More detailed data characteristics may also be implicitly reflected in the property value and EPC score estimates through their original valuations and energy performance inspections, respectively (McCord et al., 2020).

3.2.1. OLS regression

The study employs multi-variant OLS regression, a specific application of regression analysis that estimates the impact various factors have on the price of a good. It is particularly suitable for examining the average effects of variables and assessing their statistical significance (Wing & Chin, 2003). In an OLS regression model, the price of the good serves as the dependent variable, while the attributes of the good that are believed to influence utility for the buyer or consumer act as the independent variables. The resulting estimated coefficients on the independent variables indicate the relative significance of each attribute in determining the price or demand for the good. It is best able to facilitate the isolation effect of specific attributes on prices without multiple transactions for every property (Reichardt et al., 2012). A higher coefficient suggests that buyers place greater value on a particular attribute, while a lower coefficient indicates relatively less importance assigned to that attribute. This is in line with the consumer theory of Lancaster (1966) and Rosen's (1974) general theory on product differentiation which both stipulate that bundles of utility-bearing characteristics have a cumulative effect on the price of a good. Therefore, it is possible to create a dollar-weighted effect model on potential price premiums where rental or sale values are weighted against certain variable characteristics.

As a mathematical function, if retail property *X* consists of *n* unique building characteristics, the rent or sale values of property *X* are defined by the quantity and quality of all *n* characteristics:

$$X_1, X_2, ..., X_n$$

The value (*V*) of property *X* is thus described as:

$$V_x = f(X_1, X_2, ..., X_n)$$

The most simplified retail property price model is exemplified below:

$$V(X_k) = \beta_0 + \sum_{i}^{n} \beta_i X_{ik} + \epsilon i$$

In which:

$V(X_k)$ = dependent variable, implicit value characteristics *X* of the product bundle *K*

β_0 = intercept

β_i = the coefficient value of independent (control variable) *i*

X_{ik} = independent control variable of product K

ϵ_i = observed statistical error

Criticism towards the application of hedonic price modelling in real estate research has been prevalent in the housing market and it is applicable to the retail market as well. The segmented nature of the real estate market introduces complexities that can lead to biased results and erroneous statistical analysis (Wing & Chin, 2003). The risk of ommited variable bias and misspecification may arise when key variables that impact price are not captured. Conversely, including highly correlated variables, incorrectly, can distort the true pricing effect (Davis et al., 2015). To mitigate some of these issues, previous research suggests improving model specifications by incorporating more factors and expanding the sample size and geographic coverage. As such postal codes for location variables are used in this research to capture market structures at the neighborhood level - reducing measurement and omitted variable bias.

Akin to any modeling exercise examining energy performance, the robustness of the results is dependent on the data inputs. The coverage, both in terms of breadth and depth and the sample size play crucial roles in determining the robustness of the findings (C. Jones & Dunse, 1998). Fuerst and Van de Wetering (2015) argue that this is especially true when the influence of an attribute, such as energy performance, is expected to be relatively minor compared to other factors like location or age, resulting in a partial effect. Multiple regression analysis will be layered by means to control for variations in property quality and attempt to account for the different segmentation within the retail property sector. Despite the limitations of the hedonic price model, it is widely accepted as a key methodology in real estate research with a long history of successful applications in empirical studies. Other regression methods such as fixed effects and time series were not selected due to the limited variation in retail data and the limited panel data availability, where multiple observations are needed for each transaction (Diewert, 2003). Fixed effects estimation may not yield meaningful results in this case nor capture the energy premium adequately. Time series analysis is useful when the focus is on analyzing the relationship and dynamics within a single variable over time. However, the interest of the main research question lies in examining the relationship between EPC labels and rent/sale values, rather than analyzing the trend or pattern within these variables over time.

3.2.2. Econometric equation operationalisation

The effect of energy efficiency is modeled and approximated by the quantitative EI values, using the hedonic function (1) as the starting point of the analysis:

(1)

$$y = \beta_0 + \beta_t T + \beta_e EI + \sum \beta_l L + \sum \beta_r R + \sum \beta_b B + \epsilon_i$$

In which:

y = dependent variable, rent or sale transaction price

β_0 = intercept

T = transaction year dummy

EI = energy index

L = geographic regions control variables

R = retail positioning control variables

B = physical characteristics control variables

ϵ_i = observed statistical error

The function presented above is improved upon by conducting separate analyses on the variables within the rental and sales datasets, assessing their suitability for inclusion in the linear model. This assessment includes considerations of the variables' adherence to a normal distribution, their linear relationship with the target value, and the presence of multicollinearity, as discussed earlier. To incorporate certain control variables into the linear model effectively, the natural logarithm of specific control variables is applied to test the functional form of the hedonic function. This practice is commonly employed in econometric analysis to help address issues of skewness and heteroscedasticity within the sample price data and linearize a non-linear relationship between the independent variable and the dependent variable (Halvorsen & Pollakowski, 1981b). When the grouped variables are extended to each single control variable in the regression analysis, considering their statistical tests, the final, log-linear regression rental function is as follows in equation (2):

(2)

$$(Ln)R = \beta_0 + \beta_1 T + (Ln)\beta_2 EI + \beta_3 LOC + \beta_4 A + \beta_5 RT + \beta_6 SEGM + (Ln)\beta_7 POP + \beta_8 AGE + \beta_9 V + \epsilon i$$

In which:

LnR = log of rent price in €/m^2/year

β_0 = intercept

T = transaction year

EI = log of energy index

LOC = 4-digit postcode

A = location typology

RT = retail typology

$SEGM$ = segment class

POP = log of the number of residents in the area

AGE = age

V = vacancy

ϵ_i = observed statistical error

Similarly, the final, log-linear regression sale function is as follows in equation (3):

(3)

$$(Ln)S = \beta_0 + \beta_1 T + \beta_2 EI + \beta_3 LOC + \beta_4 A + \beta_5 RT + \beta_6 SEGM + \beta_7 POP + \beta_8 AGE + \beta_9 V + \epsilon i$$

In which:

$(Ln)S$ = sale price (in €/m^2)

β_0 = intercept

T = transaction year

EI = energy index

LOC = 4-digit post code

A = location typology

RT = retail typology

$SEGM$ = segment class
POP = number of residents in the area
AGE = age
V = vacancy
ϵ_i = observed statistical error

The model, with a breakdown of the variables is provided in Figure 3.1.

Figure 3.1: Control variable classification; source: author.

Control variable specification

The control variables are based on the general retail and land theories of Reilly (1929), Myrdal and Sitohang (1957), Nelson (1958), and Alonso (1964), combined with empirical evidence on the variables that influence retail rents and sale values studied in Chapter 2. Presenting the operationalisation of the conceptual framework, four groups of control variables: geographic region-, retail positioning-, physical characteristics-, and transaction type variables. An in-depth overview of the variables deployed in the model can be found in Table A.1 in Appendix A.

Transaction type: freehold vs leasehold

In the context of this study, the primary focus lies in understanding the value of real estate as demonstrated through transactions: in the form of rentals and sales. These transactions provide valuable insights into the dynamics of the retail real estate market, to examine the factors that influence property values and assess the significance of various determinants. Both rental and sale transactions were utilized in this research to enhance the sample size and broaden the scope of the research. Larger sample sizes are instrumental in bolstering the external validity of the study and its ability to generalize findings to similar contexts. This is particularly vital for informing policymakers, guiding investor decision-making, and advancing both academic knowledge and practical applications. Additionally, readily available data in the retail sector is relatively rare, which has contributed to the dearth of research in this domain. By analyzing both types of transaction data, potential biases are reduced, and more meaningful conclusions can be drawn concerning the underlying drivers of real estate value.

Geographic characteristics

There are many different methods to identify and define geographic location-based market segments for commercial property. Some of these include the availability of parking space and distance to central business districts for trade and office buildings, or access to motorways for industrial buildings (Geltner et al., 2017). For retail properties, the usual claim to success are three-fold: location, location, and location (K. Jones & Simmons, 1987). A key factor in retail attraction is determined by the location of the retail store. A novel approach is employed to control for the impact of location on property prices. Postcodes are geo-coded using GIS with a pair of latitude and longitude coordinates, allowing for a more precise assessment of the relationship between location and price dynamics. This approach is particularly significant in the context of green premium research, as it reveals the differential preferences for properties in different location typologies and how these preferences can influence price dynamics for the first time within the retail sector.

Retail positioning

Retail attraction is defined as the capability to drive consumers to the store by overcoming any physical barriers and competitive forces (Cliquet, 1992, p. 73). The positioning component of shopping behavior thus implies a reliance on footfall and population density in the surrounding areas. The different segmentation of retail typologies may also have an impact on pricing dynamics.

A further distance to the store lowers the perceived utility and consumers incur higher costs to visit. Distance, being a key inhibitor to store visits, can be conceptualized by the principle of spatial interaction theory (Fotheringham & O'Kelly, 1989); it can be understood through the concept of a ”descending spatial demand curve,” which illustrates the inverse relationship between demand and price (K. Jones & Simmons, 1987, p. 3845). While the number of footfall is undoubtedly a relevant variable with available data, it was not directly included in the model(Bolt, 2003) due to issues of multicollinearity. The "segment" variable was chosen over the "footfall" variable in both models due to its superior performance -it exhibited higher adjusted R-squared values and lower BIC values, indicating a better fit and improved model performance. However, the footfall variable was still considered in the descriptive statistics to provide further insights into the two datasets.

Physical characteristics

Another dimension in market segmentation is defined by the design and physical properties of a retail space. This was extensively studied in Chapter 2, however, certain data points such as shape, shop-frontage-block perimeter ratio, etc., were just simply unattainable. The age of buildings was categorized into new, pre-war, and post-war, reflecting the characteristic composition of Dutch and broader European properties. Another important aspect considered in the analysis is vacancy. The standard vacancy rate is typically set at a 15 percent discount (Eichholtz, personal communication, June 22, 2023), and the inclusion of this variable is to examine if this variable differs between rental and sale transactions. Property size was not included as a separate variable as it was already accounted for in the transaction price.

3.2.3. Model selection and multi-model inference

To ensure model parsimony and appropriate model selection, initial testing of structural parameter selection was conducted. This process aimed to reduce model complexity while maintaining model predictability. To ensure the highest level of explanation power while avoiding the reliance on solely the R-squared value, which always increases with the addition of new regressors, a step-wise elimination method based on the adjusted R-squared value and BIC was employed. This approach helped in retaining the most relevant variables during the model selection process.

Step-wise elimination combines aspects of both forward and backward elimination. Where the process of forward elimination, and step-wise elimination, begins with an empty regression model and progressively adds control variables one at a time. The initial variable selected for inclusion is the one with the highest correlation, but after each - variable selection - step, regressors are examined for potential elimination, following the backward elimination method.

3.2.4. Descriptive Analysis

To align with the 2050 targets established by DGBC, the classification of properties into the "High EPC" and "Low EPC" groups is based on the EPC assigned to each property. In this categorization, properties with an energy label of B or higher are included in the "High EPC" group. Conversely, properties with an energy label of C or below are classified in the "Low EPC" group. To delineate between the two, a blue color will be used to represent properties with a high EPC label (B and above), while the color orange will be used to represent properties with a low EPC label (C and below). The frequency counts of the categorical dummy variables for both rental and sale transactions can be found in Table B.1 and Table B.2, respectively, in Appendix B. It is important to note that these descriptive findings alone are not enough to draw conclusive insights, as the mean values have not been adjusted for quality-related factors. This adjustment will be taken into account in the regression analyses to provide a more accurate assessment.

Rental transactions

Table 3.1 depicts the quantitative distinction between retail spaces with a high EPC label and a low EPC label. The sample rental properties are diverse in age and type with buildings from 1850 to 2020, covering high-street properties as well as neighborhood centers and shopping malls. The average EI score falls within label A for the higher group and label D for the lower group. Interestingly, within the higher EPC label group, the rental properties demonstrate an unexpected trend of having a lower average transaction price per m^2.

Table 3.1: Descriptive statistics high vs. low EPC label - rental transactions; source: author.

Descriptive Statistics		N	Mean	Standard Deviation	Significant Difference	T-test or Mann-Whitney
Energy Label Variable						
Energy Index	High EPC	625	52.37	10.40	Yes^{++}	0.17
	Low EPC	390	135.90	37.17		
Retail Variables						
Footfall	High EPC	625	7,276.32	5,522.88	Yes^{++}	5.40 ***
	Low EPC	390	9,221.15	6,797.42		
Population within 5km	High EPC	625	102,007	98,123	No^{++}	0.01
	Low EPC	390	113,293	106,369		
Population within 10km	High EPC	625	232,462	197,731	No^{++}	2.23 **
	Low EPC	390	255,776	205,064		
Building Variables						
Age (Years)	High EPC	625	85	67.73	Yes^{++}	1.41
	Low EPC	390	104	74.66		
Size of Transaction (m^2)	High EPC	625	150.07	97.51	No^{++}	-7.25 ***
	Low EPC	390	146.37	103.76		
Lease rent (€/ m^2)	High EPC	625	240.53	190.22	No^{++}	40.45 ***
	Low EPC	390	257.81	74.54		

*Significant at the 10% level **Significant at the 5% level ***Significant at the 1% level
Based on a $^{+}$ t-test $^{++}$ Mann-Whitney test

Figures 3.2 and 3.3 offer valuable insights complementing Table 3.1, depicting the age and square meterage of each rental transaction categorized into high and low EPC groups. Notably, the properties with the highest EPC labels appear relatively young, with a majority of properties falling below the 50-year building life-cycle threshold. The data sample represents the diversity of Dutch retail real estate, incorporating some historic buildings alongside more modern ones. Furthermore, in terms of transaction size, there is not a significant difference observed between the two groups, indicating the physical size of the buildings involved in the transactions is comparable, regardless of their energy performance.

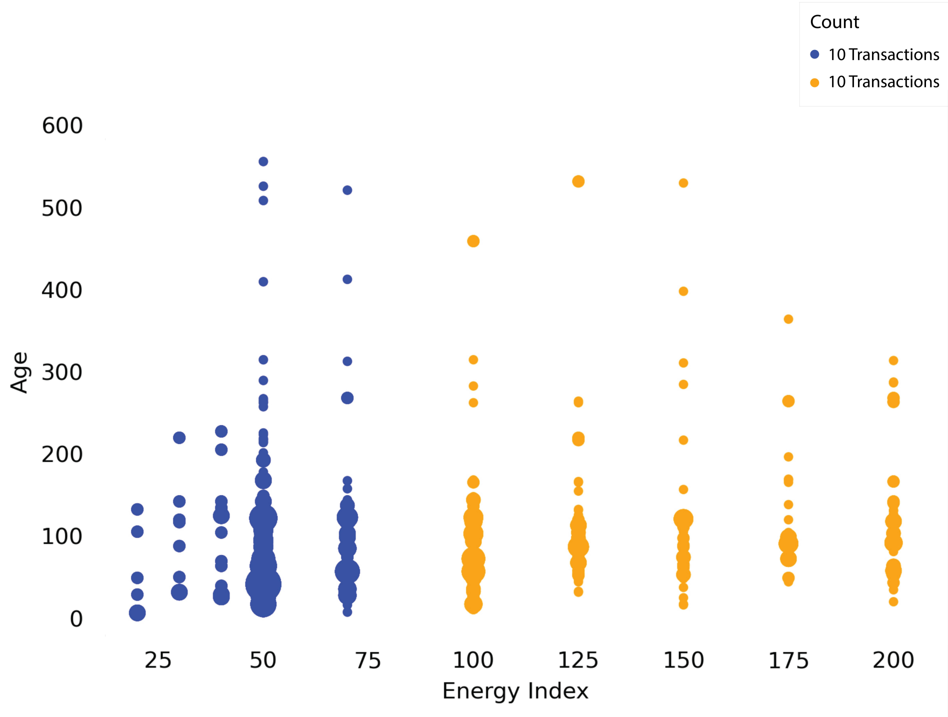

Figure 3.2: Age of rental retail properties in relation to their Energy Index; source: author.

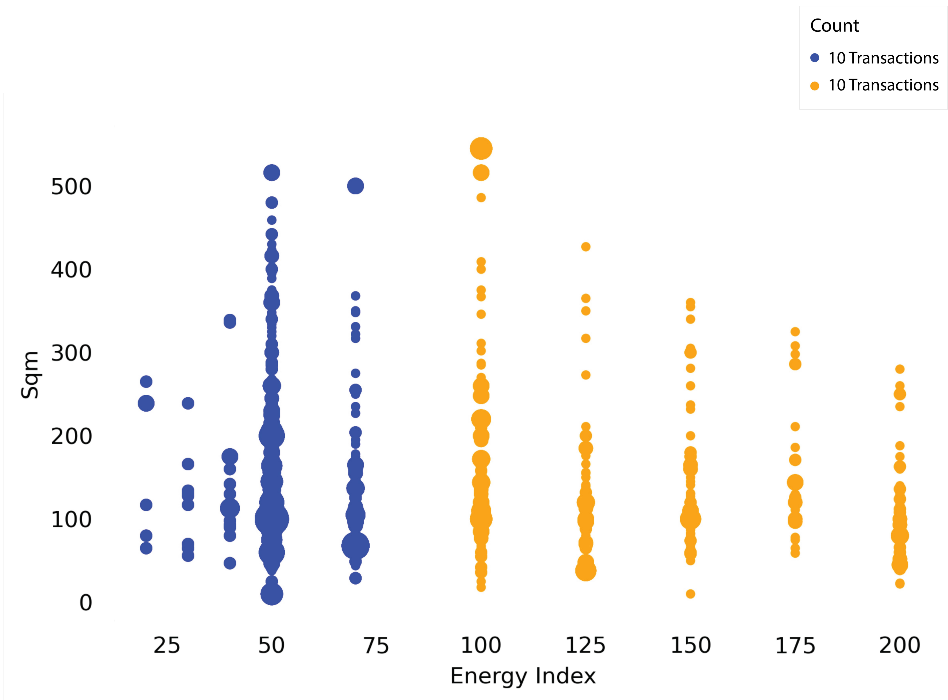

Figure 3.3: Distribution of Energy Index across rental square meterage; source: author.

Sale transactions

A summary of the descriptive statistics for sale transactions is presented in Table 3.2. The sample sale properties are diverse in age and typology with one particular property dating back to 1600 in Delft city center. The sample mean property price for high EPC buildings is €3,168.62 per m^2, higher than its energy-inefficient counterpart at €2,733.04 per m^2. The average transacted floor size exhibits an inverse relationship compared to the sale value. In the lower group, the average floor size is 187 m^2, while in the higher group, it is slightly smaller at 175 m^2. The properties with high EPC labels, on average, tend to be younger in age and have lower footfall numbers. This finding is consistent with the nature of high-street retail in the Netherlands, where older properties are more prevalent.

Table 3.2: Descriptive statistics high vs. low EPC label - sale transactions; source: author.

Descriptive Statistics		N	Mean	Standard Deviation	Significant Difference	T-test or Mann-Whitney
Energy Label Variable						
Energy Index	High EPC	220	54.38	11.71	Yes^{+}	1.72*
	Low EPC	258	140.02	36.10		
Retail Positioning Variables						
Footfall	High EPC	220	6,023.64	4,636.38	Yes^{++}	5.78 ***
	Low EPC	258	6,590.89	5,415.66		
Population within 5km	High EPC	220	69,467	72,541	Yes^{++}	-1.58
	Low EPC	254	82,253	70,617		
Population within 10km	High EPC	220	167,081	153,573	No^{++}	-0.17
	Low EPC	258	174,652	141,487		
Building Variables						
Age (Years)	High EPC	220	92	46.96	No^{++}	-2.19 **
	Low EPC	258	109	84.26		
Size of Transaction (m^2)	High EPC	220	174.63	155.44	No^{++}	-2.50 **
	Low EPC	258	187.09	182.12		
Sale Value (€/m^2)	High EPC	220	3,168.62	3.691.35	No^{++}	31.53 ***
	Low EPC	258	2,733.04	1,995.50		

*Significant at the 10% level **Significant at the 5% level ***Significant at the 1% level
Based on a $^{+}$ t-test $^{++}$ Mann-Whitney test

Figures 3.4 and 3.5 offer a visual overview, complementing the data presented in Table 3.2 with respect to the age and square meterage of each sales transaction. Notably, a majority of all properties are over 50 years old with the low EPC group containing outliers represented by very old buildings. In terms of square meterage, the average values for both low and high EPC groups show minimal differences.

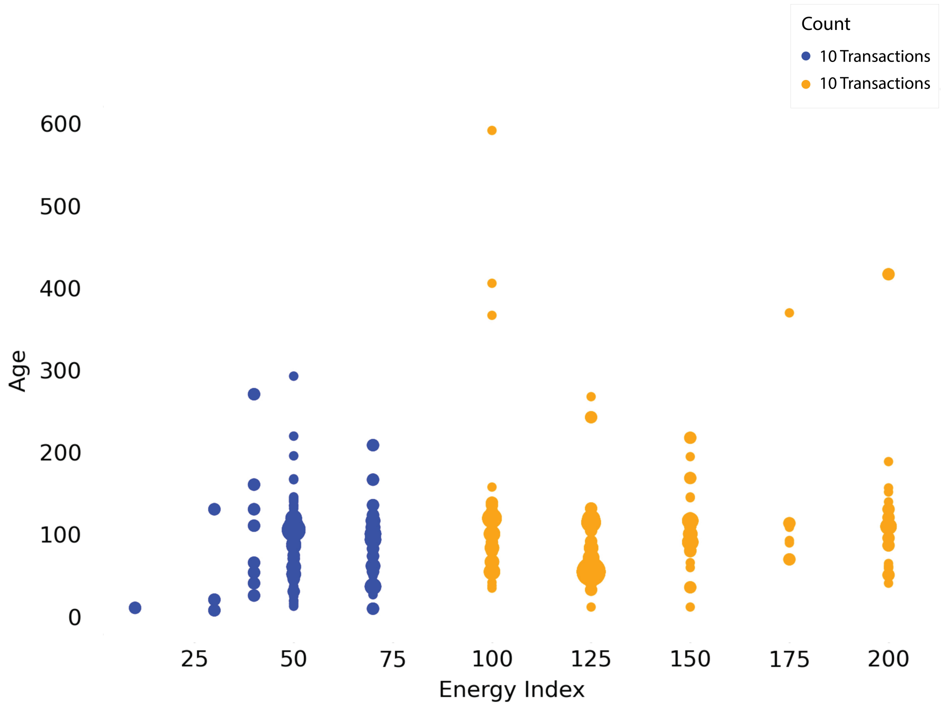

Figure 3.4: Age of sold retail properties in relation to their Energy Index; source: author.

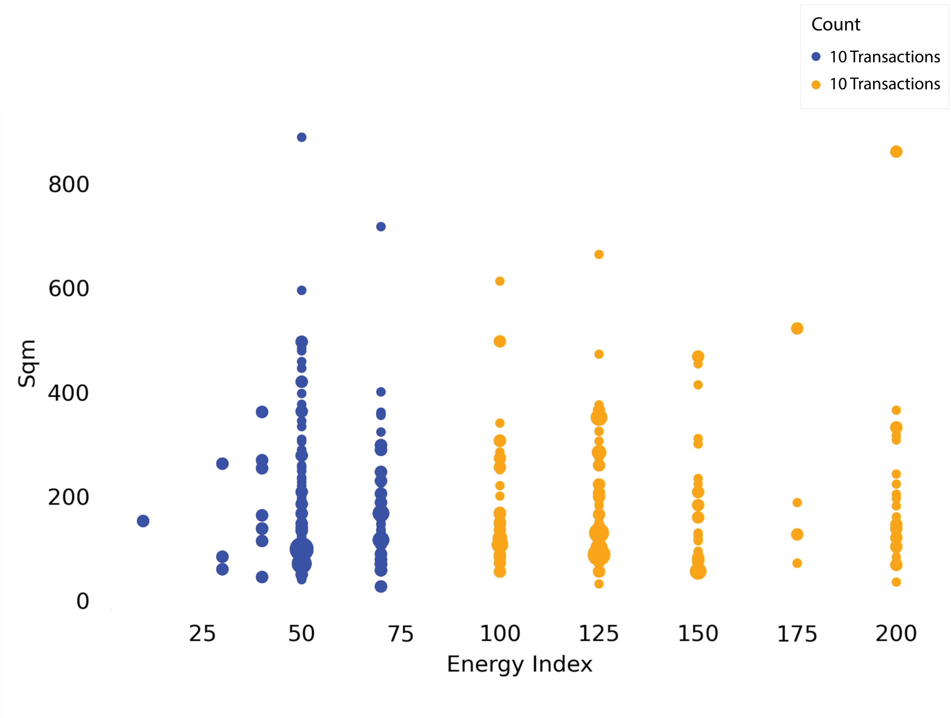

Figure 3.5: Distribution of Energy Index across sold square meterage; source: author.

4 Empirical findings

This chapter focuses on the examination of sustainability trends over time and presents findings on the relationship between energy labeling, location, and their impact on rental and sale prices. In keeping with the previous chapters, a blue color will be used to represent properties with a high EPC label (B and above), while the color orange will be used to represent properties with a low EPC label (C and below). The reported results of the regression models can be found in Table 4.1 and 4.2. A discussion regarding the implications of the hypotheses follows each analysis.

4.1. Univariate analysis

4.1.1. Rental transactions

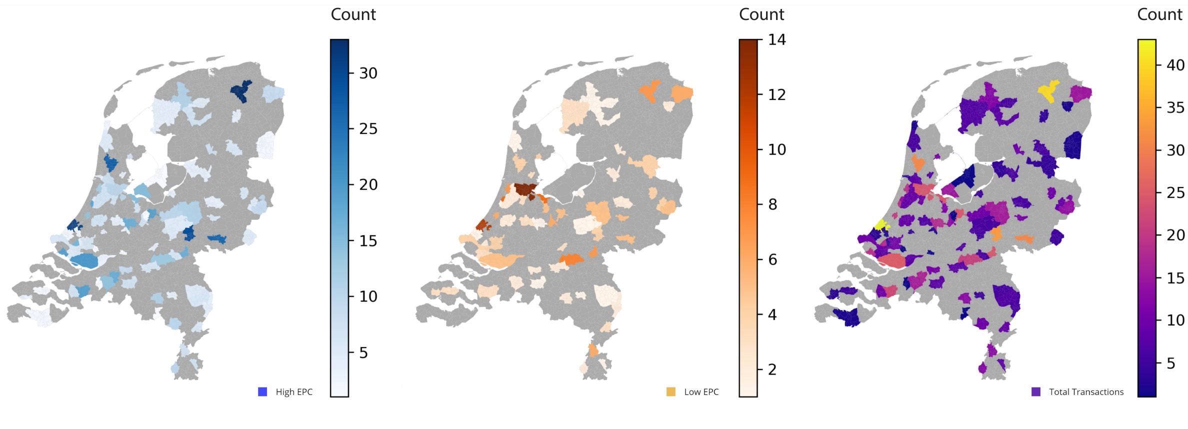

Figure 4.1: Spatial distribution of rental retail transactions from 2015 to 2021; source: author.

Figure 4.1 highlights the presence of distinct market structures and segmentation based on geographic characteristics, which contribute to variations in rental pricing. These structural characteristics exhibit specific spatial concentrations, resulting in a complex mosaic of market compositions. The observations in the rental dataset (both high and low EPC labels) are randomly distributed across the Netherlands, suggesting that the sample is representative of retail real estate properties throughout the country. However, the analysis places a clear emphasis on the Randstad areas in the Netherlands, including prominent cities such as Groningen, and Maastricht.

Sustainability over time

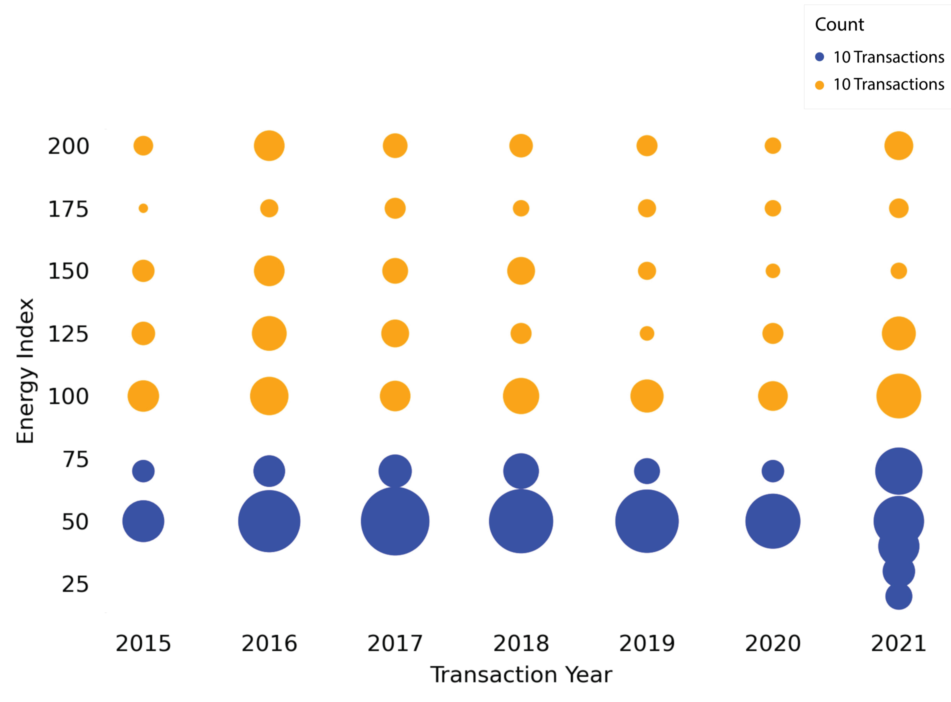

Figure 4.2: Energy Index breakdown of rental transactions over time - EPC labels B and above (in blue) and EPC labels C and below (in orange); source: author.

Figure 4.2 provides a clear visual representation of the distribution of rental properties during the transition to the new EPC regulations. Instead of observing a decline in the number of less energy-efficient buildings, it appears that high EPC buildings are either moving towards achieving net-zero energy status or are being rewarded for their prior net-zero performance. The downgrading of certain high EPC properties can also be observed for 2021. This development is intriguing, and it will be interesting to monitor how this progresses in the coming years and what policies are implemented to promote net-zero, or high-efficiency buildings.

On the other hand, the number of transactions for low EI buildings does not seem to be decreasing, but there is a noticeable increase in the stock of buildings that perform very poorly (G) compared to those rated as just 'poor' (F). This indicates a significant challenge in improving the energy efficiency of the lowest-performing buildings. While energy targets are set, there is currently no legislation in place to incentivize property owners and retailers to take action in this regard (Colliers, 2021).

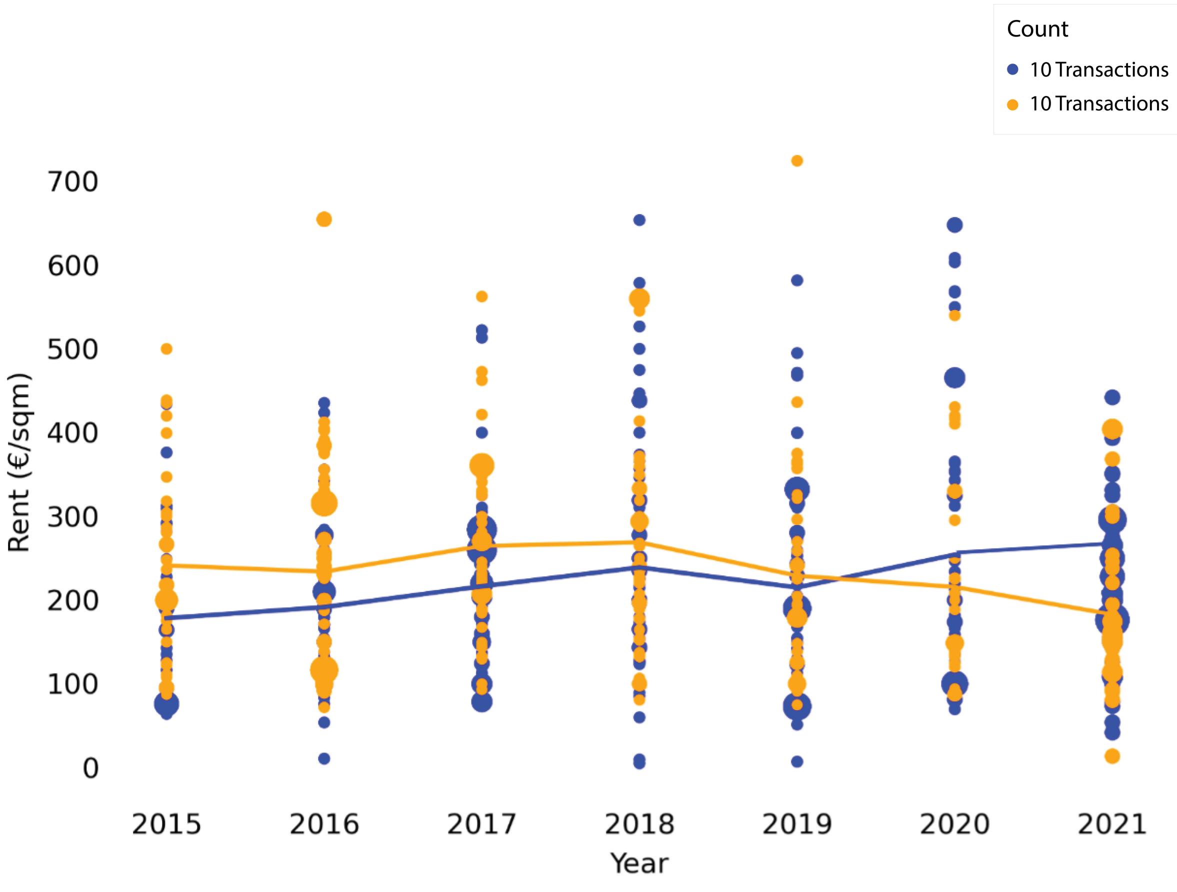

Figure 4.3: Historical rental retail transactions distinguishing between EPC labels B and above (in blue) and EPC labels C and below (in orange); source: author.

As a continuation of Figure 4.2, when examining rental prices, Figure 4.3 provides a visual representation of the trends for high and low EPC properties. This cross-correlation reveals that low EPC properties produced the highest rents in 2017 and 2018, but there has been a downward trend ever since. This trend could be attributed to both a sustainability effect and a potential ”browning effect” resulting from more retail properties being registered for EPCs. Conversely, rental prices for high EPC properties show an upward trend, giving the first indication of the presence of an energy premium in Dutch rental retail.

4.1.2. Sale transactions

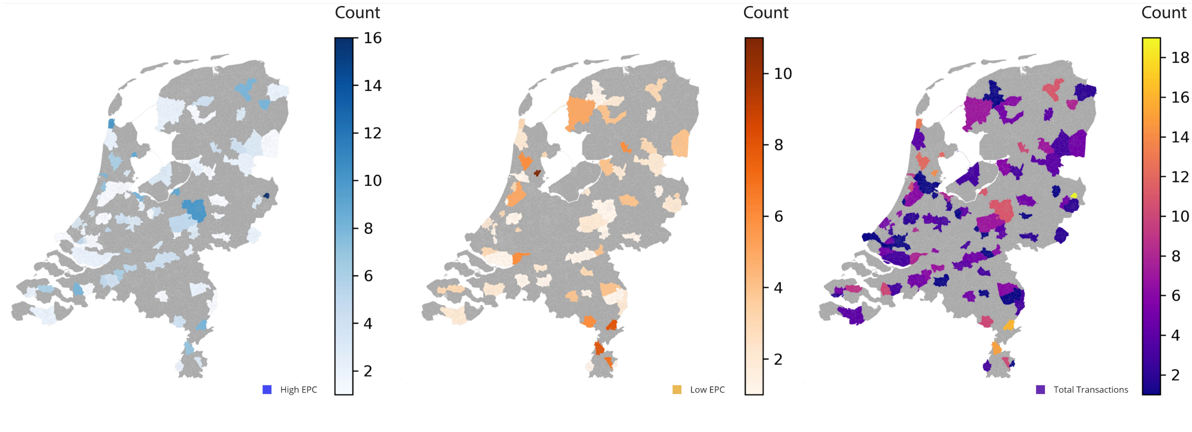

Figure 4.4: Spatial distribution of sale retail transactions from 2015 to 2021; source: author.

Figure 4.4 presents a geographical representation of both high and low EPC retail properties, as well as an overview of the total sales transactions. While the observations in the dataset are randomly distributed throughout the Netherlands, it is important to note that there is a disparity in the number of observations between the rental and sales databases. The distribution of sales transactions is skewed towards smaller regional centers such as Oldenzaal, Purmerend, and Roermond, rather than the more prominent Randstad cities. This may indicate the possibility of geographic data bias, despite the dataset's extensive coverage of different location typologies.

Sustainability over time

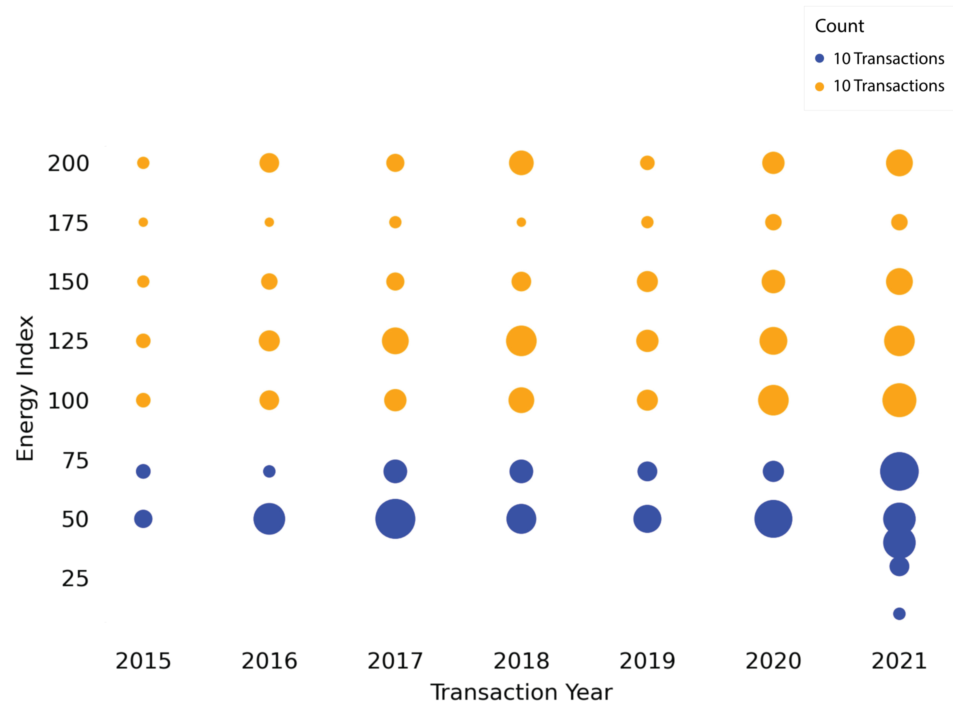

Figure 4.5: Energy Index breakdown of sales transactions over time - EPC labels B and above (in blue) and EPC labels C and below (in orange); source: author.

Figure 4.5 visually presents the distribution of sold properties during the transition to the new EPC regulations, providing a clear depiction of the changes in the distribution pattern. Once again, it is observed that the number of low EPC properties did not decrease significantly, but there is a notable increase in the categorization of very high, energy-efficient buildings. A smaller number of observations can also be witnessed. As a result, it can be observed that the transactions of both high and low EPC labeled properties correlate with the total number of transactions in each year.

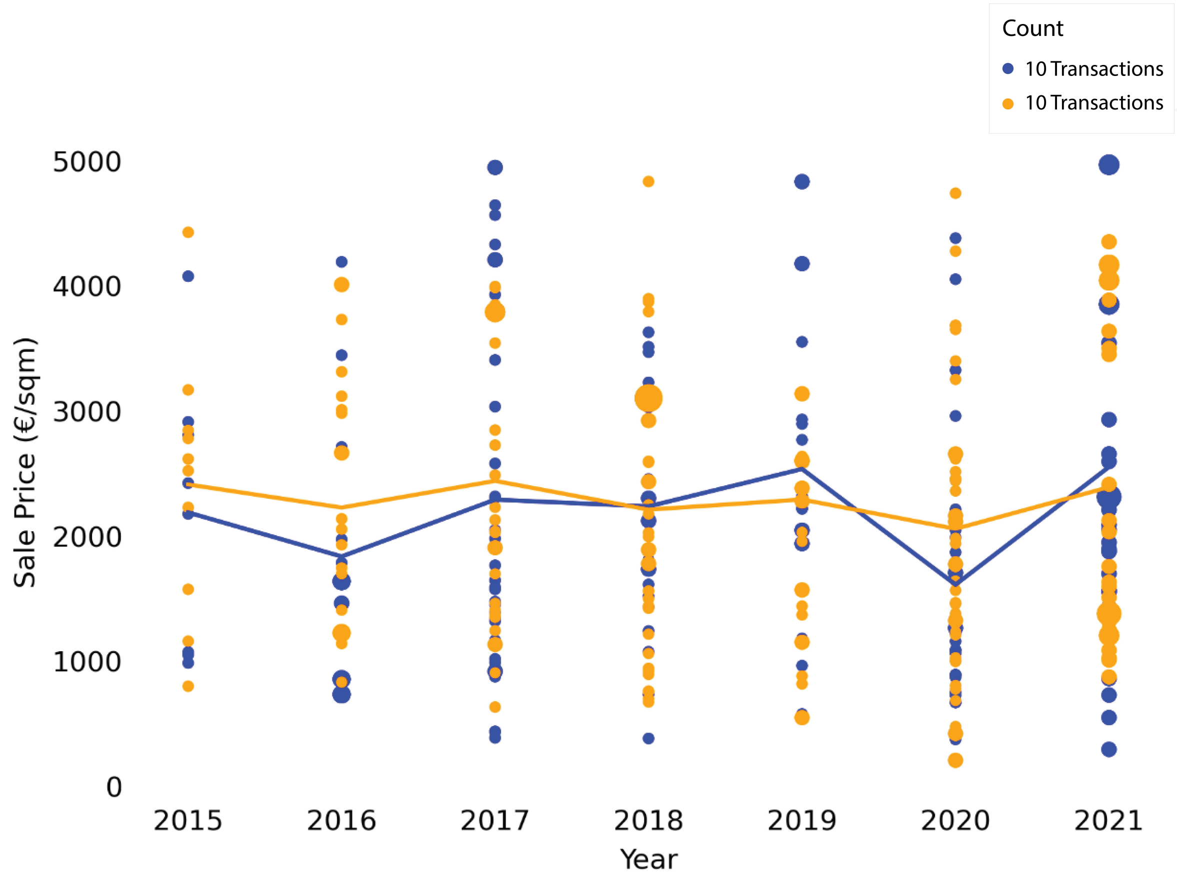

Figure 4.6: Historical sales retail transactions distinguishing between EPC labels B and above (in blue) and EPC labels C and below (in orange); source: author.

When plotting sale prices in relation to the transaction year and distinguishing between high and low EPC properties, no clear trends emerge, as shown in Figure 4.6. The average sale prices for high EPC properties appear to be more volatile, experiencing significant dips in 2016 and 2020, but ultimately reaching a higher average transaction sale price in 2021 compared to 2015. On the other hand, the average sale prices for low EPC properties show a flatter line, indicating less price volatility. However, when comparing the sale prices in 2015 to those in 2021, there does not appear to be a significant increase in the average sale price for low EPC properties. Since no clear trend is evident from the graphical analysis, the regression analysis can provide further insights into the relationship between EPC labels and transaction prices.

4.2. Energy premium

Table 4.1 reports the results of the OLS regression model on the natural log of rent per m^2. Table 4.2 reports the results of the OLS regression model on the natural log of sale prices per m^2. When selecting reference categories for dummy coding, it was important to consider a group that encompasses a substantial number of observations, while also reflecting a distinct representation and meaning compared to the other categories. This ensured a meaningful and representative comparison among the different groups being analyzed (C. Jones & Dunse, 1998).

4.2.1. Results of rental regression

Table 4.1: Market rent OLS regression results; source: author.

	(1) Energy	(2) Geographic	(3) Retail	(4) Physical
Energy index	0.1081**	0.0854***	0.1230***	0.1144***
	(0.0466)	(0.0204)	(0.0391)	(0.0390)
2015 Dummy	-	-	-	-
2016 Dummy (1 = yes)	-0.0142	0.0262	0.0370	0.0275
	(0.0956)	(0.0813)	(0.0806)	(0.0802)
2017 Dummy (1 = yes)	0.0661	0.0926	0.0931	0.0733
	(0.0953)	(0.0881)	(0.0786)	(0.0780)
2018 Dummy (1 = yes)	0.0859	0.0992	0.0924	0.0738
	(0.0938)	(0.0901)	(0.0794)	(0.0788)
2019 Dummy (1 = yes)	0.0336		0.0466	0.0340
	(0.1008)	(0.1001)	(0.0840)	(0.0836)
2020 Dummy (1 = yes)	0.0360	0.0077	-0.0214	-0.0202
	(0.1033)	(0.0991)	(0.0871)	(0.0868)
2021 Dummy (1 = yes)	-0.0552	0.2310	0.2122**	0.1921*
	(0.1021)		(0.1056)	(0.1048)
Location Fixed Effects	N	Y	Y	Y
Location Typology:				
City Center (1 = yes)		0.6230***	0.3177***	0.3158***
		(0.0624)	(0.0666)	(0.0661)
Regional Center -Large (1 = yes)		0.1340**	0.1362**	0.1154**
		(0.0606)	(0.0568)	(0.0565)
Regional Center -Small		-	-	-
City District Center (1 = yes)		0.5267***	0.1621***	0.1572***

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Table 4.1 – continued from previous page

	Model (1)	Model (2)	Model (3)	Model (4)
		(0.1239)	(0.1249)	(0.1247)
Retail Typology:				
Fashion & Luxury			-	-
Daily Use (1 = yes)			0.2689***	0.1840***
			(0.0653)	(0.0673)
Free Time (1 = yes)			-0.1808**	-0.2612***
			(0.0802)	(0.0818)
In & Around the House (1 = yes)				-0.1434**
				(0.0577)
Leisure (1 = yes)			0.1907	-0.0985*
			(0.1092)	(0.0591)
Segment:				
A1 (1 = yes)			0.5854***	0.5796***
			(0.0946)	(0.0939)
A2 (1 = yes)			0.3717***	0.3461***
			(0.0898)	(0.0891)
B1 (1 = yes)			0.2324***	0.2217***
			(0.0829)	(0.0823)
B2 (1 = yes)			0.0194	0.0088
			(0.0825)	(0.0821)
C			-	-
Population within 5km			0.0057	0.0259
			(0.0511)	(0.0543)
Population within 10km			0.3048***	0.2253***
			(0.0493)	(0.0529)
Vacancy Dummy (1 = yes)				-0.1559***
				(0.0370)
Constant	4.9369***	4.6287***	0.8917**	1.7102***
	(0.1815)	(0.1427)	(0.3726)	(0.4253)
R-squared	0.0286	0.3684	0.4360	0.4494
R-squared Adj.	0.0219	0.3370	0.4067	0.4172
N	1015	1015	1015	1015

* Significant at the 10% level ** Significant at the 5% level *** Significant at the 1% level

Discussion

> *H1: A higher Energy Performance Certificate label positively correlates with a higher rental price premium.*

The natural log OLS model encompassing spatial location dummies for rental transaction prices is presented in Table 4.1. A positive and significant coefficient would support H1 above. Model (1) reports a basic model relating rent to transaction year and EI; the coefficient of EI represents the impact of a higher EPC grade on the rental price. This regression, based upon 1015 observations explains 2.19 percent of log rent and estimates the energy premium to be significant, at about 11 percent.

In model (2), the estimated coefficient for EPC ratings reduces slightly at 8.5 percent in retail rents but grows in significance to the 0.05 level. The other variables of interest are the added postcodes (location fixed effects) and location typology that enhanced the regression's explanatory power (adjusted R-squared). Rent in "city centers" is over 62 percent higher than that of a "small regional center", about 10 percent higher than that of a supporting "city district center", and almost 50 percent higher than that of a "large regional center".

In model (3) the variables measuring retail positioning are added to the model. The results indicate that there is a substantial premium associated with a higher building segment at the highest significance level. Population within a 5 km radius is insignificantly different from zero however, there is a substantial premium associated with population within a 10 km radius. In contrast to the initial expectation that "fashion and luxury" retail typology would yield higher rents, "daily use" retail outperforms it by 27 percent at the highest level of significance. A highly significant rent premium of 12 percent is associated with the EI in this regression.

Model (4) adjusts for the age range and vacancy of the retail property. However, during the stepwise process, age ranges were systematically eliminated due to the lack of correlation. Vacancy in rental retail properties exhibits roughly the expected 15 percent discounting effect. A highly significant rent premium of 11 percent is associated with the EI in this regression.

Key Takeaways

Although the descriptive statistics initially suggest that low EPC properties had a higher average rent value compared to high EPC properties, the findings from the rental regression analysis reveal a different picture. After controlling for all relevant factors, the results indicate that high EPC properties yield a higher rent value. The coefficient of the EI variable remains positive and statistically significant across all model specifications. This positive relationship, coupled with the high explanatory power, is consistently observed throughout the models. Table 4.1 provides empirical support for H1. This suggests that higher energy-efficient properties are valued more in the rental market, reflecting the importance placed on sustainability and energy performance by tenants. The inclusion of additional control variables is highlighted by the increase in the R-squared value, from 2.19 percent to 41.72 percent. The latter value is comparable to the one reported in Eichholtz et al. (2010), and Fuerst and McAllister (2011a).

With regards to location typologies, in line with expectations, "city centers" yield higher rents compared to their counterpart "town centers" and "supportive centers". This is also reflected in the high premiums segments A1 and A2 generate over a segment C property. The COVID-19 pandemic had a slight, but not statistically significant, impact on transactions in 2020, with a 2 percent decrease compared to previous years. However, there was a notable recovery in 2021 where transactions increased by 12 percent compared to 2015. This suggests a potential rebound in market activity, in line with CBS (2023) price indices.

4.2.2. Results of sale regression

Table 4.2: Market sale OLS regression results; source: author.

	(1) Energy	(2) Geographic	(3) Retail	(4) Physical
Energy index	0.0007	0.0008	0.0013*	0.0010
	(0.0007)	(0.0006)	(0.0006)	(0.0005)
2015 Dummy	-	-	-	-
2016 Dummy (1 = yes)	-0.2281	0.1044	0.0961	0.0789
	(0.1934)	(0.1992)	(0.1976)	(0.1883)
2017 Dummy (1 = yes)	-0.2409	-0.0389	-0.0402	-0.0408
	(0.1833)	(0.1892)	(0.1864)	(0.1772)
2018 Dummy (1 = yes)	-0.1131	0.1482*	0.1690**	0.1712**
	(0.1816)	(0.1890)	(0.1864)	(0.1779)
2019 Dummy (1 = yes)	-0.2424	0.0002	0.0079	-0.0643
	(0.1935)	(0.1935)	(0.1883)	(0.1800)
2020 Dummy (1 = yes)	-0.4919***	-0.1075	-0.0807	-0.0166
	(0.1796)	(0.1853)	(0.1837)	(0.1751)
2021 Dummy (1 = yes)	-0.0398	0.2877***	0.1379***	0.1338***
	(0.1722)	(0.1815)	(0.2967)	(0.2872)
Location Fixed Effects	N	Y	Y	Y
Location Typology:				
Regional Center -Small		-	-	-
City Center (1 = yes)		0.3445	0.2777	0.4841**
		(0.6025)	(0.6058)	(0.2288)
Retail Typology:				
Fashion & Luxury			-	-
Daily Use (1 = yes)			0.4124***	0.2495**
			(0.1191)	(0.1200)
Free Time (1 = yes)			-0.3502**	-0.2806*
			(0.1615)	(0.1643)
In & Around the House (1 = yes)			-0.2467**	-0.3525***
			(0.1143)	(0.1160)

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Table 4.2 – continued from previous page

	Model (1)	Model (2)	Model (3)	Model (4)
Leisure (1 = yes)			-0.0341*	-0.0985*
			(0.1883)	(0.1859)
Segment:				
A1 (1 = yes)			0.0142	0.1620
			(0.1755)	(0.1681)
A2 (1 = yes)			0.3394**	0.2786*
			(0.1671)	(0.1611)
B1 (1 = yes)			0.0980	0.1600**
			(0.1549)	(0.1497)
B2 (1 = yes)			0.0680	0.0733
			(0.1493)	(0.1424)
C			-	-
Population within 5km			-0.1016	0.0172
			(0.1700)	(0.1645)
Population within 10km			0.2598***	0.1475**
			(0.0564)	(0.0576)
Age:				
< 10 years				-2.3258***
				(0.4644)
11-30 years				-0.3842**
				(0.1666)
31-50 years				-0.2145
				(0.1459)
50+ years				-
Vacancy Dummy (1 = yes)				-0.2624***
				(0.0800)
Constant	7.8461***	7.6457***	7.5458***	6.5061***
	(0.1759)	(0.0766)	(0.0788)	(0.6505)
R-squared	0.0460	0.4451	0.4852	0.5279
R-squared Adj.	0.0318	0.3943	0.4342	0.4823
N	478	478	478	478

* Significant at the 10% level ** Significant at the 5% level *** Significant at the 1% level

Discussion

H2: A higher Energy Performance Certificate label positively correlates with a higher sale price premium

The natural log OLS model encompassing spatial location dummies for sale transaction prices is presented in Table 4.2. It follows the same additive measures as the rental model above. A positive, and statistically significant coefficient in the analysis would provide evidence supporting H2. Model (1) reports a basic model relating rent to transaction years and EI; this regression, based upon 478 observations explains 3.18 percent of log sale prices. Interestingly, in the first model, the only variable that demonstrates statistical significance is the 2020 dummy. This variable indicates a significant, 50 percent decline in sale values compared to 2015 which can be partially attributed to the impact of the COVID-19 pandemic. However, it is noteworthy that the EI variable has a very small effect of 0.07 percent with zero significance. This suggests that there is a need for additional explanatory variables and more comprehensive control factors for a robust regression analysis.

Model (2), controls for important geographic proxies such as postcodes (location fixed effects) and location typologies. Properties located within ”city centers” command higher rents compared to ”small regional centers” at the 0.05 significance level. The remaining location typologies did not meet the criteria for inclusion during the stepwise elimination process. The estimated coefficient for EPCs is still negligible at 0.08 percent and remains statistically insignificant.

In model (3) retail positioning variables to distinguish retail typologies, segment classes, and populations within the area are added. The estimated coefficient for EI jumps in significance at the 0.10 level but the coefficient still remains less than 1 percent. Similar to the rental model, the ”daily use” retail typology yields higher sale prices compared to the expected top performer: ”fashion and luxury”, exhibiting a premium of 18 percent at the 0.05 significance level. The analysis reveals that the population within a 10km radius has a greater impact on sale prices compared to the population within a 5km radius once again. Furthermore, in the segment category, A2 properties exhibit higher premiums at a higher level of significance even when compared to A1 buildings.

In model (4) where all control variables are included, the estimated coefficient of EI indicated a sale price premium of 0.1 percent but is insignificantly different from zero. Building age classification and vacancy dummies were adjusted for in model (4). The results indicate that there is a substantial discounting effect associated with newer buildings at high significance levels. These findings highlight the complexity of the relationships observed, particularly when comparing similar property types in different market areas. For example, the observed premiums or discounts associated with energy efficiency may be influenced by the location effect rather than solely the EPC grade. Vacancy levels in sold retail properties were found to have a stronger negative correlation with prices than anticipated, showing a 26 percent decrease in prices at the highest significance level.

Key Takeaways

The analysis leads to the conclusion that older properties situated in ”city centers” tend to command higher sale prices. These findings are in line with the general retail theories proposed, which suggest larger centers with larger catchment areas have a strong, positive influence on property prices (Reilly, 1929). Vacancy rates within sale properties have a more significant impact on transaction prices compared to rental transactions, even higher than the expected 15 percent effect. Notably, transaction years 2018 and 2021 exhibit higher transaction prices at a high significance level when compared to 2015. Regarding retail typologies, ”daily use” demonstrates the highest price correlation, with ”fashion and luxury” coming in next, and ”in and around the house” showing the lowest prices. The model has a final explanatory power (adjusted R-squared) of 48.2 percent in line with existing literature (Eichholtz et al., 2010; Fuerst & McAllister, 2011a).

Based on these results, H2 which suggests a positive premium associated with energy efficiency in sale prices, cannot be confirmed due to the small estimated coefficient and lack of statistical significance. However, it is important to note that this does not necessarily mean there is no premium but rather indicates the need for further investigation and consideration of other factors that may influence sale prices in the retail sector.

5

Discussion & Insights

This research presents one of the first systematic analyses of the financial implication and spatial distribution of energy efficiency using the Dutch retail market as a laboratory. The findings of this study strongly support a positive connection between energy efficiency and financial performance. These results are not only intuitive but also align with previous research by Eichholtz et al. (2010) in the US office sector, Chegut, Eichholtz and Kok (2011) in the UK office sector, and Chegut et al (2016) in the Dutch housing market with a caveat that it is difficult to compare between sectors and regions.

The rental OLS model exhibits the EPC coefficient to be positive and highly statistically significant, indicating that superior energy efficiency is considered, and valued as a positive attribute in the rental market; the 11.44 percent rental premium is extensively controlled by geographic, retail, and physical characteristics. In the sale OLS model, a positive coefficient of the EPC variable is observed, albeit marginally, and without statistical significance. This outcome is attributed to the spatial distribution of the sales dataset, particularly lacking transactions in the Randstad area, known for its high concentration of retail activity within the Netherlands. With a larger and more representative data sample that better reflects the nature of Dutch retail, more robust and significant results can be observed. The hypothesis that the rental premium would surpass the sale premium due to the smaller barrier in investment holds partially true, despite the uncertain significance of the sales premium.

5.1. Understanding the EPC label

The introduction of the new EPC calculation scheme in the Netherlands in 2021 resulted in the enhancement of labels for existing highly efficient retail properties. However, there was no observed decline in the number of transactions from properties labeled C and under, both in rental and sale transactions. This suggests that lower labeled properties are not sufficiently incentivized to improve their energy efficiency. The lack of a regulatory push and concrete plans to reach energy targets may explain the current focus on long-term goals without immediate action. The study of industrial ecology places significant emphasis on the efficient use of resources, particularly energy, and its consumption. From this perspective, the real estate sector must fulfill present needs while ensuring the ability of future generations to meet their own requirements. A crucial aspect of achieving sustainable development in real estate is understanding the significance of the EPC label. It equips various stakeholders with insights into the financial implications of energy retrofits, facilitates the implementation of energy-efficient building practices, and contributes to reduced overall consumption. In contrast, without sufficient incentives to invest in energy-efficient measures, the concept of the Tragedy of the Commons (Ostrom, 2008) becomes ever so relevant, resulting in higher energy consumption and environmental impact.

By embracing the principles of sustainable development through the understanding and utilization of EPCs, responsible resource management (in the broadest terms) can be fostered within the real estate industry. In the subsequent sections of this chapter, the findings for each sub-question will be presented, leading to a comprehensive response to the main research question. The implications of these results will be discussed, along with any contrasts with previous studies. The implications for theory, practice, and policies will also be explored, culminating in final conclusions regarding whether a correlation can be found between the energy performance indicator and the value of a property, as reflected in its rental or sales price.

SRQ1: Determinants for Dutch retail real estate

Beyond the direct effects of energy efficiency in both the rental and sales market, unsurprisingly, the location typology and segment of a property significantly influence retail real estate activities. ”City centers” demonstrate a remarkable 32 percent premium in rental transactions and an even higher 48 percent premium in sales transactions all at the highest significance level. Furthermore, in both the rental and sales market, the segment class of retail properties exhibits significant premiums ranging from 28 to 58 percent. This finding aligns with traditional retail theories (Alonso, 1964; Christaller, 1980; Reilly, 1929), providing valuable empirical evidence to support this relationship.

A real estate market outlook for 2022-2024, published by Bouwinvest (2022), one of the largest institutional investors in the Netherlands, found that despite challenges faced by a section of the retail market due to the COVID-19 crisis, the total volume of investments in retail assets amounted to €2.3 billion in 2020; this amount was comparable to total investments in the previous years. Notably, local shopping centers and supermarkets have emerged as significant contributors to this volume of transactions due to strong financial performance. However, due to the prevailing uncertainty surrounding future vacancy rates and transactions in main shopping streets, there have been relatively fewer transactions involving assets in these locations. This can explain why the retail typology, ”daily use” outperformed a high-earning category like ”fashion and luxury” in both regression results. In the same vein, this may partially explain the spatial distribution of sales transactions and why were more prevalent and biased around ”smaller regional centers” instead of the Randstad ”city centers”. It appears that broader retail market forces hold a greater significance in determining transaction prices, overshadowing the influence of purely the energy label. However, for occupiers and renters alike, cities with the largest catchment areas will likely continue to offer the best sales opportunities and a greater chance of recovery amidst difficult market conditions.

SRQ2: Sustainable value drivers

The findings of this study reinforce the notion that higher energy labels in rental markets indeed play a significant role in creating a price premium for retail real estate. The positive correlation between energy labels and rental prices serves as an important driver for sustainable value in the rental market. The inconclusive results concerning sales values highlight the ongoing need for improved data access and collection in order to draw more robust conclusions.

From a policy perspective, it is evident that while binding legislation has been introduced for the office market, similar measures are not yet in place for the retail sector. The absence of concrete pathways and legislative pressure to achieve long-term, energy efficiency targets set forth by the EU and the Netherlands means that there is little incentive for retail investors to prioritize sustainability in their properties. Given the higher energy consumption and higher m^2 footprint in the retail sector, it becomes even more important to implement energy efficiency measures and incentivize sustainability practices in this domain. To achieve the 50-60 percent energy reduction in the sector by 2050 (DGBC, 2023), policymakers should consider comprehensive strategies that encompass energy efficiency measures in refrigerated and non-refrigerated retail, recognizing the varying energy consumption patterns and addressing them accordingly. It is essential for occupiers and investors alike, to recognize their role in the Vicious Circle of Blame and work together to break the cycle.

Occupier's perspective

The findings of this research present an opportunity for renters to reduce their long-term operations costs by selecting energy-efficient properties or advocating for energy retrofits to be initiated by property owners. Given the energy crisis in Europe, this becomes particularly pertinent to potential cost savings. Notably, the major trend of online sales, accelerated by the COVID-19 pandemic, witnessed webshops experiencing the highest growth in sales (28.5 percent). In contrast, clothing stores, shoe stores, and food and beverage outlets recorded steep declines in sales (from 18.7 to 33.9 percent) (Bouwinvest, 2022). This situation compels occupiers to adopt strategic measures in drawing back customers. One approach could be enhancing the brand image by contributing to sustainability goals by opting for greener, more environmentally friendly spaces. This move resonates with consumers who prioritize the sustainability of the products they purchase, making it a compelling factor for attracting and retaining clientele.

Investors' perspective

From the investor's perspective within the Vicious Circle of Blame, no demand from occupiers for sustainable buildings prevails (D. Cadman, 2000). However, a 2021 RICS sustainability report (2021) revealed that 80 percent of European respondents believe that investor demand for green buildings has increased in the past twelve months. This growing interest in sustainable properties can serve as intrinsic motivation for both companies and individual owners to transition towards a more energy-efficient built environment, even if they are primarily driven by cost considerations. In cases where the added rental and/or capital value increase resulting from energy retrofits do not fully cover the investment costs, regulatory forces should incentivize investors to move towards energy neutrality. Such incentives would play a crucial role in encouraging investors to make sustainable choices, contributing to the broader goal of creating a more energy-efficient and environmentally conscious real estate sector.

Valuation perspective

The results of this research offer valuation professionals a host of valuable insights. An understanding of energy premiums enhances accuracy in property valuations by empowering professionals to provide informed investment advice to potential investors, highlighting the financial advantages of energy-efficient properties, which yield an 11 percent premium in rental income and lower operational costs. By recognizing the energy premium, valuation experts can also better assess risk, considering the decreased likelihood of future expenses associated with energy consumption in energy-efficient properties. Furthermore, analysis of market trends and tenant or buyer preferences for energy-efficient spaces becomes possible, aiding professionals in offering market-driven insights (Ecorys, 2016). For sale retail properties, analogous benefits apply with certain distinctions due to property ownership dynamics. Valuation professionals can capitalize on the premium of energy efficiency improvements, enhancing overall market value with potential long-term cost savings, as well as lower operational expenses.

5.2. Policy recommendations

The sustainability transition in the retail market is currently facing challenges due to a lack of significant pressure from consumers and the government. EPCs are not a silver bullet and must work in union with other policy instruments. In light of the research findings, several policy recommendations are proposed below as a starting point to address these challenges and seize opportunities for progress.

Stage 1 - Proficiency

The importance of data collection and data quality must be emphasized. One of the largest barriers witnessed in this research and also noted in past research is the lack of quality data within real estate. By requiring comprehensive guidelines, standards, and procedures to ensure the reliable collection, processing, and reporting of data, there will be a significant increase in high-quality data availability. The Netherlands can serve as a valuable case study, and the focus can be extended to encompass all EU nations. This concerted effort would contribute to a more robust and reliable data landscape. The credibility and trustworthiness of the information provided to clients and stakeholders are also enhanced. This paves the way for researchers to more precisely and periodically measure the relationship between energy efficiency and market performance. In the long term, this serves as the basis for more informed decision-making and promotes energy efficiency across the European real estate sector.

Stage 2 - Persuasion

Raise awareness among consumers regarding the energy performance of retail stores. In the office market, employees are increasingly demanding sustainability and well-being initiatives from their employers, prompting companies to invest in creating healthier and more environmentally friendly work environments. These efforts not only enhance their attractiveness to new talent but also boost employee productivity and overall satisfaction (S. Sayce, A. Sundberg, B. Clements, 2010). However, the situation in the retail market is different, where sustainability initiatives tend to focus primarily on the product level - consumers often prioritize the sustainability of the products they purchase but may overlook the energy consumption of the physical stores (Colliers, 2021). One significant aspect that is commonly overlooked is the energy consumption required for climate control in retail spaces, especially due to open doors. This *blind spot* among consumers means that there is a need to raise awareness about the environmental impact of retail operations beyond just the products. Similar to the promotion of EPCs from mere transactional requirements to visual displays in property advertisements for rent or sale, the next step could involve prominently showcasing energy performance using expressive graphic presentations directly on the properties. Voluntarily eco-labels such as BREEAM and LEED have employed this tactic already (UKGBC, n.d.; USGBC, n.d.). By doing so, consumers can make informed choices and drive demand for more energy-efficient options (Lainé, 2011). This approach would draw attention to the energy consumption of stores and encourage energy-saving practices from the consumers' point of view.

Promote the development of an energy-literate society. In line with the aforementioned recommendation, a crucial long-term objective in policy-making should be to ensure that all information surrounding energy consumption in retail and all other sectors is easily accessible and comprehensible for individuals from diverse backgrounds.

Stage 3 - Practice

Set ambitious, intermediary energy-efficiency targets for the retail sector, aligned with national and international climate goals. This can serve as a benchmark for progress and motivate stakeholders to take meaningful actions to reduce energy consumption well before the 2050 deadline. It also ensures that targets do not diminish over time and maintain a steady momentum. Drawing upon successful lessons learned from the residential and commercial office sectors, the retail industry can adopt, and expand upon the energy efficiency targets set by the Netherlands to potentially, other EU states. One significant step towards incentivizing energy efficiency could be moving away from property taxes that penalize it, such as market-value taxes, and transitioning towards those that reward it, like site-value taxes already implemented in Denmark and Estonia (European Commission et al., 2013). Implementing such tax systems could likely lead to a higher energy premium. By avoiding annual taxation of associated capital gains, private benefits would increase, which would raise the likelihood of investments in energy retrofits. This approach could increase the likelihood, of investment in energy retrofits, reducing the need for direct government intervention.

Within the Netherlands, introducing financial incentives such as tax credits or grants for retail property investors to achieve higher EPC labels could help offset the initial costs of energy-efficient upgrades and encourage wider adoption of sustainable practices. Learning from the residential and office sectors, implementing such financial incentives can serve as a powerful catalyst, generating increased interest in energy-efficient solutions.

5.3. Contrast with previous studies

This research contributes to the literature on real estate valuation for policymakers, real estate professionals, and stakeholders interested in promoting sustainability and energy efficiency in the built environment. Consistent with previous studies, OLS regression remains a prominent methodology for empirical research investigating the impact of energy performance on property values. Notably, this study enhances the existing literature by employing spatial considerations at the intra-urban level to explore the spatial aggregation of EPCs and understand how the retail market perceives and values them differently.

This study aligns with previous research conducted in the office and residential sectors, indicating that sustainable properties tend to command higher rental values. However, when it comes to sales values, the findings are inconclusive, which further underscores a recurring challenge faced by many studies in the field— the lack of accessible and reliable data. The scarcity of reliable data may elucidate the contrast between the findings of this research and the sole two prior related studies in the retail sector. As noted earlier, the authors of the earlier studies, themselves, acknowledged limitations and potential bias within their data, offering suggestions for future research to address these gaps.

5.4. Limitations and future research

Further investigation is required to fully understand the factors influencing energy premiums in sold retail properties. A limitation in this research is the conspicuous absence and shortcomings of data, a prevalent issue faced by all researchers in this field. While the data used in this study represents the best available information at the time, it is essential to recognize its limitations and continue to seek more comprehensive and high-quality data sources for future research. Some factors, such as the floor discounting effect and specific energy-related details, were not accounted for in the model due to data unavailability. For example, the effective price of a -2 level is not the same as a ground or +4 level. To improve the accuracy of future research, it is recommended to incorporate additional variables, consider a larger and more diverse sample size, and expand the geographical coverage.

Furthermore, considering the dynamic and heterogeneous nature of markets, there is a constant need for updated studies that employ more comprehensive and extensive data. As the retail landscape evolves over time, it becomes crucial to conduct research that captures the latest developments in an ever-changing market. By continuously improving model specifications and incorporating relevant data, researchers can gain deeper insights into the complex relationships between energy certification, property values, and market dynamics.

There is also a knowledge gap around the *supply* of energy-efficient buildings, with limited evidence reporting the statistically significant incremental costs associated with energy-efficient real estate construction (Robinson, 2015). While construction costs vary, little is known about the extent of these variations and whether they are changing over time due to the introduction of substitute or complementary sustainable building products and regulations. Addressing these gaps in knowledge would provide valuable insights into the cost of energy-efficient practices in the real estate industry and help inform policy decisions aimed at fostering sustainable development.

5.5. Conclusion

In conclusion, this study highlights the importance of sustainable practices in the real estate sector and adds to the growing body of literature emphasizing the positive relationship between energy efficiency and property prices. Moving forward, addressing data limitations and ensuring comprehensive data collection will be critical in advancing research on the sales side and enhancing our understanding of how energy performance impacts property values across different markets and geographies.

Signing the Paris Climate Agreement has led the Netherlands to commit to a significant reduction of CO_2 emissions for 2030 and 2050. One of the main agreements entails additional energy savings in the built environment. Energy efficiency continues to be a crucial policy priority for governments - achieving reductions in carbon emissions and striving for carbon neutrality in the real estate sector are seen as essential strategies to drive change. The introduction of mandatory EPC labeling for property transactions reflects a growing emphasis on tackling these challenges. The current state of commercial retail shows a lack of labeled properties. If energy labels were to be made mandatory for all non-labeled retail properties, it is projected that less than 25 percent of these properties would receive an energy label of B or higher. In comparison, the percentage of office properties meeting the same energy label requirement would be around 50 percent, showcasing a comparatively lower level of energy efficiency in the retail sector. This is noteworthy, especially considering the larger overall square meterage footprint of the retail sector and greater consumption of energy per m^2.

The study draws from the principles of industrial ecology, with a specific emphasis on understanding the systemic relationships between society, the economy, and the natural environment. By analyzing historical rental and sale market transactions from 2015 to 2021, this research presents some of the earliest evidence on the economic value of energy certification in the retail sector. The findings suggest that the relationship between energy performance certification labels and rental and sale prices is complex and multifaceted. Stationary premia for higher EPC-certified rental transactions are roughly 11 percent, on a price per m^2 basis. Selling prices of energy-efficient transactions are more marginal and complex, particularly when accounting for data limitations and changing model specifications. This discrepancy may be attributed to various factors, such as data bias and inefficiencies, which need further exploration in a perfect world where empirical data flows abundantly and are meticulously measured for academic research.

This linkage between sustainability and financial benefits creates a strong incentive for investors, and businesses, alike to adopt energy-efficient measures, since currently, substantial upfront, often on-balance, capital costs are incurred to carry out energy retrofits of existing building stock. This study also stands out as one of the first to conduct spatial analyses of EPCs for the retail sector, providing valuable insights for informed policy-making while considering geographic variation. Findings around the spatial distribution of retail premiums confirm that retail properties have higher rents and higher values in larger centers with higher footfalls, fully in line with the traditional retail theories of Reilly (1929), Alonso (1964), and Christaller (1980). Looking ahead, regulatory efforts should prioritize concentrated data collection, enhancing energy literacy, extending initiatives to encompass all EU member states, and establishing ambitious intermediary targets for the retail sector in the Netherlands. By addressing these recommendations, policymakers can advance energy-efficient practices within the retail sector, contributing to a more responsible future for the real estate industry.

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A

Appendix A

Table A.1: Control Variable Overview; source: author.

Note: This table only presents the statistically significant variables found in both models.

Control Variable	Description
Energy Index	The energy performance of the transacted property in a numeric format from 0 to 200+.
Energy Performance Label	The energy performance of the transacted property in a categorical format from A+++++ to G.
Rental Price	The transaction rent per square meter of lettable floor area retail space.
Sale Price	The transaction sale value per square meter of lettable floor area retail space.
Transaction Year	The specific year in which a property was sold or rented out to a tenant and/or owner.
4-Digit Post Code	The specific neighborhood or a part of a larger city: the first two digits of the postal code indicate the region, and the last two digits indicate the specific neighborhood within that region.

Continued on next page

Table A.1 – continued from previous page

Control Variable	Description
Location Typology:	The retail locations are categorized into three primary types, depending on their function: 'City & Town Centres', 'Supportive Centres', and 'Residual Centers' per Locatus categorization. However, it is worth noting that the last type, 'Residual Centers', was not found in the dataset.
City Center	Pertaining to the most important retail areas in the Netherlands, the vicinity must host over 400 shops; falls under the 'City & Town Centres' group of which the inner cities of Amsterdam, Rotterdam, the Hague, and others are a part.
Regional Center- Large	Refers to the primary commercial hub of a town or city, typically hosting between 200 to 400 shops in the retail sector; falls under the 'City & Town Centres' group. Examples of such areas include Delft Center and Bussum Center.
Regional Center- Small	Similar to the Large Regional Center, this category refers to the primary commercial hub of a town or city but only hosts 100 to 200 shops; falling under the 'City & Town Centres' group. Examples are Franeker Center or Putten Center.
City District Center	This typology is characterized by its systematic development and is always an extension of a city or town center; falling under the 'Supportive Centres' group Examples of such centers include Amsterdam-Osdorpplein and Nijmegen-Dukenburg and contain 50 to 100 points of sale.
Retail Typology:	The umbrella term encompassing multiple industries that share similar characteristics per Locatus categorization.
Fashion & Luxury	Retail spaces specializing in clothing, accessories, and luxury goods
Daily Use	Retail spaces focused on everyday necessities and convenience products, including grocery stores but excluding the hotel, restaurant, and catering (HORECA) sector.
Free Time	Retail spaces catering to recreational and entertainment products, such as books, hobbies, and electronics.

Continued on next page

Table A.1 – continued from previous page

Control Variable	Description
In & Around the House	Retail spaces related to home improvement, furniture, and interior decor.
Leisure	Retail spaces offering services and products for leisure activities, such as sports equipment, travel, and entertainment.
Segment:	Determined by the ratio between the maximum footfall number of a retail area and the footfall number of a specific outlet (percentage of the busiest counting point). This concept is based on the division established by Drs. E.J. Bolt (2003) in his book titled *Winkelvoorzieningen op waarde geschat*.
A1	75 to 100 percent.
A2	50 to 74 percent.
B1	25 to 49 percent.
B2	10 to 24 percent.
C	5 to 9 percent.
Footfall	On an average Saturday, the footfall of a property is determined by visiting 24 different counting points where footfall counters record data for 5 minutes, four times a day. These footfall countings are carried out twice a year at various locations by Locatus. To ensure accuracy, the results are then compared with the transaction numbers of several anchor stores, which helps generate reliable footfall figures for an average Saturday. This value is not used directly in the model due to multicollinearity but rather as a calculation for the Segment class, above.
Population within 5 KM	The number of residents living within a walking time of 5 KM.
Population within 10 KM	The number of residents living within a walking time of 10 KM.
Age	The age of the property is defined as the number of years elapsed since its construction year. The categorical division aligns with typical construction eras, helping to capture the characteristics and building standards prevalent during different periods.

Continued on next page

Table A.1 – continued from previous page

Control Variable	Description
< 10 years	This category includes buildings that are relatively new; they are likely to benefit from the latest construction technologies and energy-efficient design practices.
11-30 years	These properties include buildings that first started to emphasize the sustainability and energy efficiency in building design and construction. This time period also corresponds to a focus on urban renewal and regeneration projects.
31-50 years	These properties may have been built during a time when energy efficiency was not a primary concern, and build in a haste given the context of the Netherlands (Berghauser Pont & Haupt, 2007). Many of these buildings can benefit from energy-efficient upgrades or retrofits.
50+ years	Buildings in the category belong to an era when energy efficiency was not a central consideration in construction and have reached their designed lifespan. Some of these properties may have historical or architectural significance, which could influence their market value.
Vacancy	A binary variable to indicate if the building is vacant at the time of survey by Locatus. (1=yes)

B

Appendix B

B.1. Rental Regression Model

Table B.1: Rent model count statistics; source: author.

Descriptive Statistics	Description		Count
Geographic Regions Variables			
Segment	A1	High EPC	85
		Low EPC	77
	A2	High EPC	88
		Low EPC	71
	B1	High EPC	232
		Low EPC	118
	B2	High EPC	172
		Low EPC	101
	C	High EPC	48
		Low EPC	23
Location Typology	City Center	High EPC	190
		Low EPC	115
	Regional Center- Large	High EPC	183
		Low EPC	138
	Regional Center- Small	High EPC	189
		Low EPC	109
	City District Center	High EPC	15
		Low EPC	11
	District Center- Large	High EPC	34
		Low EPC	13

Continued on next page

Table B.1 – continued from previous page

Descriptive Statistics	Description		Count
	Inner Urban Shopping Area	High EPC	9
		Low EPC	3
	Big Box Retail Park	High EPC	5
		Low EPC	1
Retail Positioning Variables			
Vacancy	(1 = yes)	High EPC	207
		Low EPC	125
Retail Typology	Fashion & Luxury	High EPC	167
		Low EPC	144
	In & Around the House	High EPC	58
		Low EPC	32
	Daily Use	High EPC	28
		Low EPC	33
	Services	High EPC	60
		Low EPC	26
	Free Time	High EPC	29
		Low EPC	10
	Leisure	High EPC	24
		Low EPC	7
	Catering	High EPC	10
		Low EPC	
	Detail Other	High EPC	17
		Low EPC	8
	Other	High EPC	22
		Low EPC	5

B.1.1. Assumptions Testing

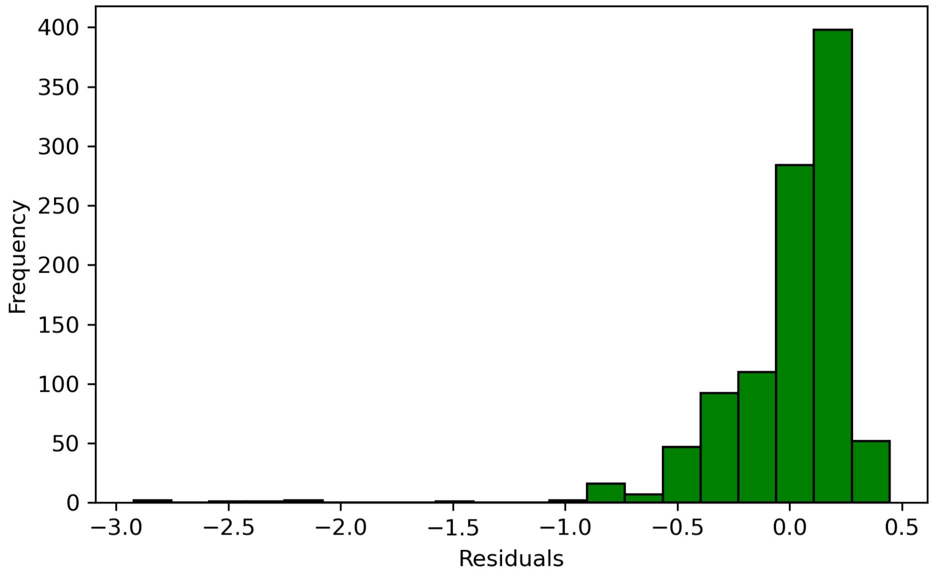

Figure B.1: Histogram residuals dependent variable- LN rent; source: author.

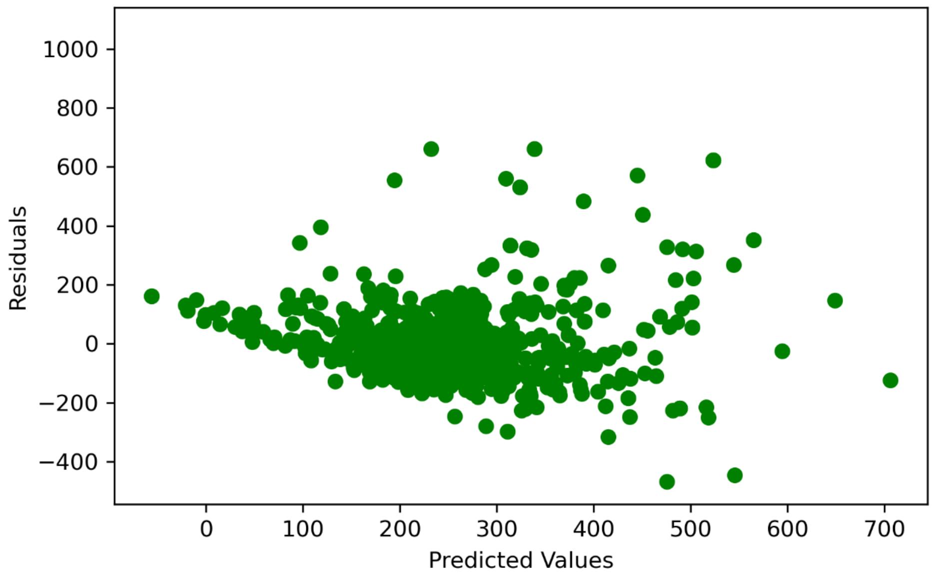

Figure B.2: Scatterplot standardized residuals against predicted values- LN rent; source: author.

B.2. Sale Regression Model

Table B.2: Sale model count statistics; source: author.

Descriptive Statistics	Description		Count
Geographic Regions Variables			
Segment	A1	High EPC	10
		Low EPC	32
	A2	High EPC	44
		Low EPC	40
	B1	High EPC	89
		Low EPC	103
	B2	High EPC	58
		Low EPC	60
	C	High EPC	14
		Low EPC	14
Location Typology	City Center	High EPC	29
		Low EPC	45
	Regional Center- Large	High EPC	69
		Low EPC	96
	Regional Center- Small	High EPC	101
		Low EPC	93
	City District Center	High EPC	3
		Low EPC	3
	District Center- Large	High EPC	13
		Low EPC	17
Retail Positioning Variables			
Vacancy	(1 = yes)	High EPC	80
		Low EPC	79
Retail Typology	Fashion & Luxury	High EPC	52
		Low EPC	83
	In & Around the House	High EPC	13
		Low EPC	29
	Daily Use	High EPC	22
		Low EPC	21
	Services	High EPC	15
		Low EPC	17
	Free Time	High EPC	11
		Low EPC	9
	Leisure	High EPC	5
		Low EPC	8
	Detail Other	High EPC	11

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Table B.2 – continued from previous page

Descriptive Statistics	Description		Count
		Low EPC	4
	Other	High EPC	6
		Low EPC	4

B.2.1. Assumptions Testing

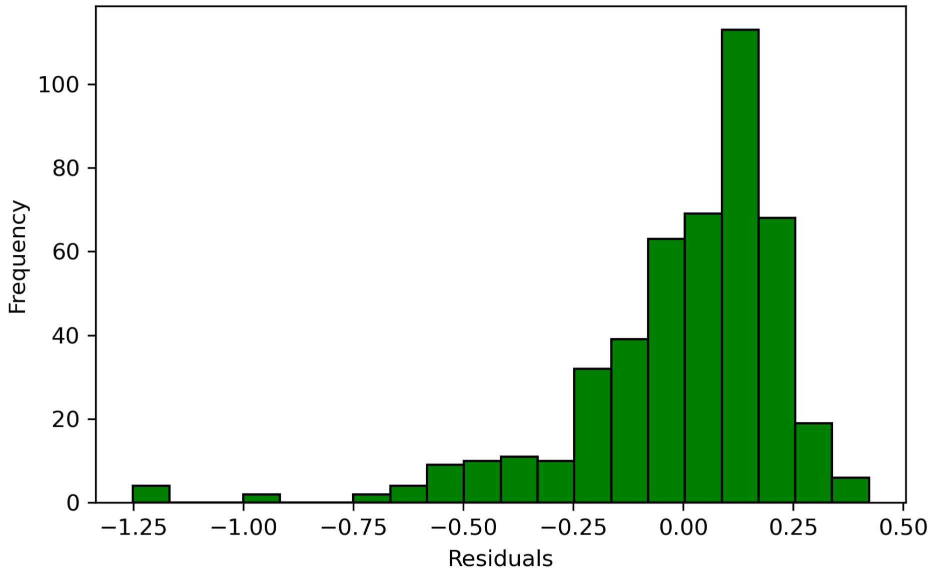

Figure B.3: Histogram residuals dependent variable- LN rent; source: author.

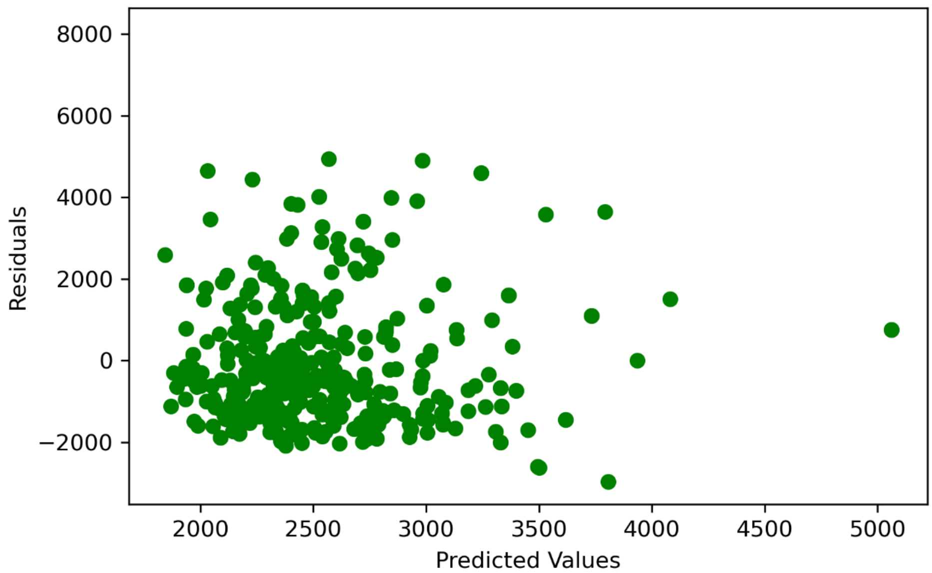

Figure B.4: Scatterplot standardized residuals against predicted values- LN rent; source: author.