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The Positive and Negative Effects of Sustainability on Real Estate Transaction Prices

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ABSTRACT

In last decades, there is a trend to renew buildings and make them more sustainable. Studies have shown that energy measures (as an aspect of sustainability) often increase the value of real estate. The effect of other sustainability measures on real estate values, however, is unknown. This study examines the relationship between multiple sustainability aspects and the transaction prices of different types of real estate. For this study, we used official data on commercial real estate transactions from the Land Registry Office in the Netherlands and sustainability assessment scores from a Dutch sustainability consultant. In total, 10,652 real estate transaction prices between 2012 and 2023 and corresponding sustainability scores were used to perform regressions and hedonic imputation analyses. The results show that, opposed to energy, other aspects of sustainability often correlate negatively with transaction prices in the lower segment of sustainable real estate. These aspects correlate positively in the upper segment of sustainable real estate.

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Commercial real estate (CRE); sustainable real estate; hedonic regression; real estate pricing; hedonic imputation

1. Introduction

In recent years, there has been a growing emphasis on the need for more sustainable buildings. On international level, sustainability is a very well embedded topic on the political agenda as the United Nations (UN) stated that making real estate more sustainable is key to achieving global climate goals (ILO & & United Nations Environment Programme Finance Initiative, 2022).

In the Netherlands, this has led to a bundle of sustainability regulations regarding the built environment. These regulations often specifically target energy performance for housing and office buildings. Previous studies have shown that energy efficiency generally has a positive effect on the value of residential property (Aroul & Rodriguez, 2017; Pride et al., 2017; Cajias et al., 2019; Lambourne, 2022; Mironiuc et al., 2021). Many studies also show a similar effect of energy on offices (Chegut et al., 2014; Devine & Kok, 2015; Eichholtz et al., 2010; Kok & Jennen, 2010; Fuerst & McAllister, 2011b; Holtermans & Kok, 2019; Mangialardo et al., 2019; Lambourne, 2022; Overbeek et al., 2023).

Sustainability, however, is much broader than energy efficiency. For instance, aspects regarding the environment, health, user quality and the adaptability of a building are also considered aspects of sustainability. Yet, little is known about the effects of sustainability measures, other than energy efficiency, on residential real estate and offices. Moreover, property types other than residential property and offices also play a role in achieving the global climate goals. Even less is known about the effects of sustainability performance on the value of these property types.

Our aim, therefore, is to investigate the relationship between sustainability measures (in a broad sense) and real estate values for commercial real estate (also in a broad sense[1]). The focus is on the transaction price as an approximation of the value. In the remainder of this article we therefore use the term transaction price instead of value. We pursued the aim by using official data on commercial real estate transactions from the Dutch Land Registry Office in the Netherlands and sustainability assessment scores from a Dutch real estate consultancy.[2] The latter data

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source allowed us to examine the effect of multiple sustainability dimensions on real estate prices with hedonic regression models with the goal to answer the following question: how do sustainability measures affect commercial property prices?

Section 2 provides an elucidation of the broad concept of sustainability and the definition and dimensions used in this study. In section 3, the data and methodology is further elucidated and in section 4, the findings are presented. Section 5 closes with conclusions and further discussions proposed by the results.

2. Background

2.1. The Definition of Sustainability

Sustainability is a very broad concept. Many studies have focussed on gathering used definitions, extracting common grounds, identifying dimensions and formulating better fitting definitions. Warren-Myers (2012) and Berardi (2013) found that there are over one hundred definitions of sustainability. Moore et al. (2017) selected over 200 studies and identified 24 different definitions. One of the simplest definitions they found was: "… sustainability is the capability of being maintained at a certain rate or level" (Gruen et al., 2008, p. 1580). Regarding real estate development, the question arises what it is that should be maintained. In this regard, Ruggerio (2021) points out that sustainability and sustainable development are often used as synonyms, but that the contamination of sustainability and development can be perceived as contradictory: it is impossible to pursue economic growth in a limited world. Redclift (2006) explains this by stating that growth of the global population will inherently lead to increased strain on the environment. Also, as technology advances, the people's expectations and needs increase. The production of goods (or development of real estate) is therefore inherently unsustainable. One might argue that sustainability can be achieved by downsizing consumption, but others suggest that downsizing has limits for a society to function effectively (Redclift, 2006). Contradictory or not, there is more awareness nowadays for sustainable development of real estate. To structure these developments, the World Commission on Environment and Development (WCED: World Commission on Environment & Development, 1987) categorized sustainability into social, economic and ecological dimensions.

Considering our aim – investigating the relationship between sustainability measures and real estate prices – a multidimensional approach to sustainability broadens the scope of this study. Various sustainability aspects could have a different effects on prices and, furthermore, the effects could be different on different types of real estate (housing, office, industry, etc.). From these many relations (Figure 1), mainly the relationship between the ecological dimension (energy in particular) and residential property and office buildings have been studied so far. This study contributes to the body of knowledge by looking at multiple aspects of sustainability and multiple property types.

2.2. Implications of Sustainability Performance

Enhancing sustainability could mean that buildings become more energy-efficient, healthier, more environmentally friendly and all in all less damaging for the planet. From investors' point of view, it would be

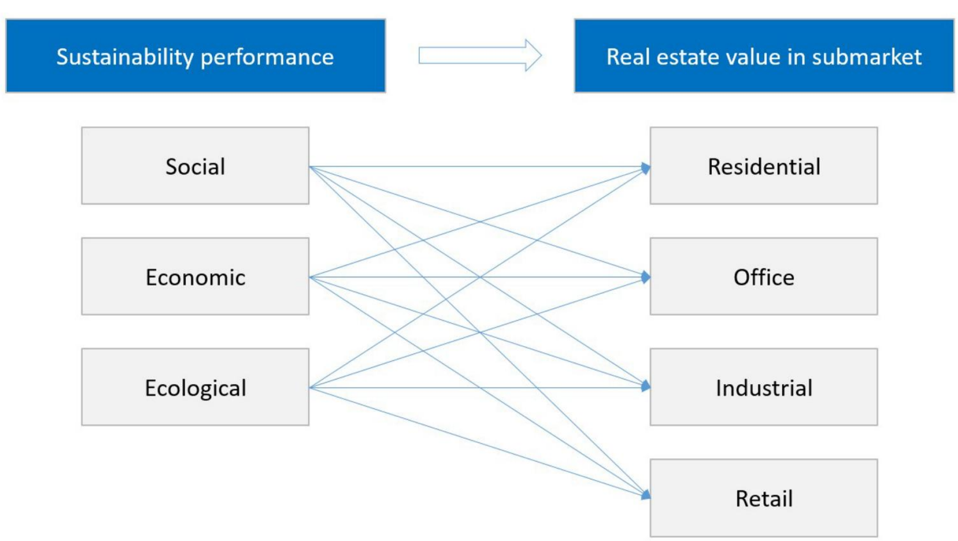

Figure 1. Relationship sustainability and real estate submarket price.
Source: Authors' own creation.

very welcome if sustainability would provide financial benefits. Such benefits could increase the demand for sustainable buildings and could boost sustainability in real estate in general. Aliagha et al. (2013) mention the lack of interest or demand as one of the barriers in the development in sustainable buildings. Aliagha et al. (2013) and Yudelson (2016) also point out that limited awareness and understanding of sustainable property could be a cause. Regarding awareness, Falkenbach et al. (2010) notice that there is a lack of evidence that sustainability measures in general increase the value of real estate. Since then, there were no studies found that investigated the effect of sustainability on prices in a broad sense. If this study could determine the financial value of sustainability measures, it will increase understanding of sustainable property and may, therefore, contribute to breaking down the barriers of sustainable development.

2.3. Effects of Certification

Many studies focus on environmental certification as predictor of real estate value (Chegut et al., 2014; Devine & Kok, 2015; Fuerst & McAllister, 2011a; Holtermans & Kok, 2019; Mangialardo et al., 2019; Overbeek et al., 2023). These certifications cover most, if not all, dimensions of sustainability. BREAAM certifications, for instance, cover 'management', 'energy use', 'health and well-being', 'pollution', 'transport', 'land use', 'ecology', 'materials' and 'water' (Sayce et al., 2007, p. 631). Studies on the effect of such certificates, however, also measure something else than merely the sustainability of real estate. They measure the psychological effect of a certificate on the real estate value. E.g. if two buildings have exactly the same sustainability performance, but only one is certified, this one may be valued higher, because there is an actual proof of sustainability. Benefield et al. (2019) proved this effect for green certified homes. This study contributes to the body of knowledge by not looking at the certification status, but only looking at the sustainability scores.

3. Data & Methodology

3.1. Data

Data from three sources in the Netherlands were used in this study: transaction data from the Land Registry Office (Cadastre), property information from the Key Register Addresses and Buildings (BAG) and sustainability scores from the real estate consultancy firm W/E advisors. The transaction prices from the Cadastre are used as approximation for real estate values. The sustainability scores from W/E advisors are used as independent variables. The information from the BAG is used to control for other effects (other than sustainability) that may influence the price.

In total, W/E advisors reported 3,473 projects in the database. Projects refer to buildings that they assessed on their sustainability performance in the years between 2010 and 2022. Some buildings are entered into the database two or more times, because they were assessed before and after a renovation. These double entries were not removed, because the assessment scores are not duplicates. They differ before and after a renovation and are useful in the analyses if the price of the building in the according year is selected (price before renovation and price after renovation). The sustainability assessment is performed on five main scores, which are linked to the categories as provided by the WCED (1987). These scores are Energy, Environment (ecological), Health, User quality (social) and Future prospects (economic) as illustrated in Figure 2. As shown, the scores were built up in the data from lower sub scores.

The 3,473 projects were linked to addresses (BAG), which correspond to 79,866 individual buildings. The observations were then linked to real estate transactions (Cadastre) and corresponding transaction prices in the years between 2010 and 2022. After that, observations with pre-renovation sustainability scores were linked to transactions from before the assessment dates. Observations with post-renovation sustainability scores were linked to transactions that occurred after the assessment dates. After these filters and other data cleaning (removal of incomplete cases/omitted variables) 10,652 observations remained for the final analyses. The observations seem randomly distributed over the Netherlands (Figure 3).

3.2. Methodology

To analyse the effect of sustainability performance on real estate price, linear regressions and hedonic imputations were performed.[3] Both techniques are described in the subparagraphs below.

3.2.1. Hedonic Regressions

The starting point of the analyses is a log-linear regression function as denoted in equation (1).

$$ln\ P_i^t = \alpha + \sum_{t=1}^{T} \delta^t D_{it} + \sum_{k=1}^{K} \beta_k c_{ik} + \beta_l s_{il} + \varepsilon_i^t, (t = 0, \dots, T), \tag{1}$$

where $ln\ P_i^t$ = the natural logarithm of the real estate price for property i at period t; α = the

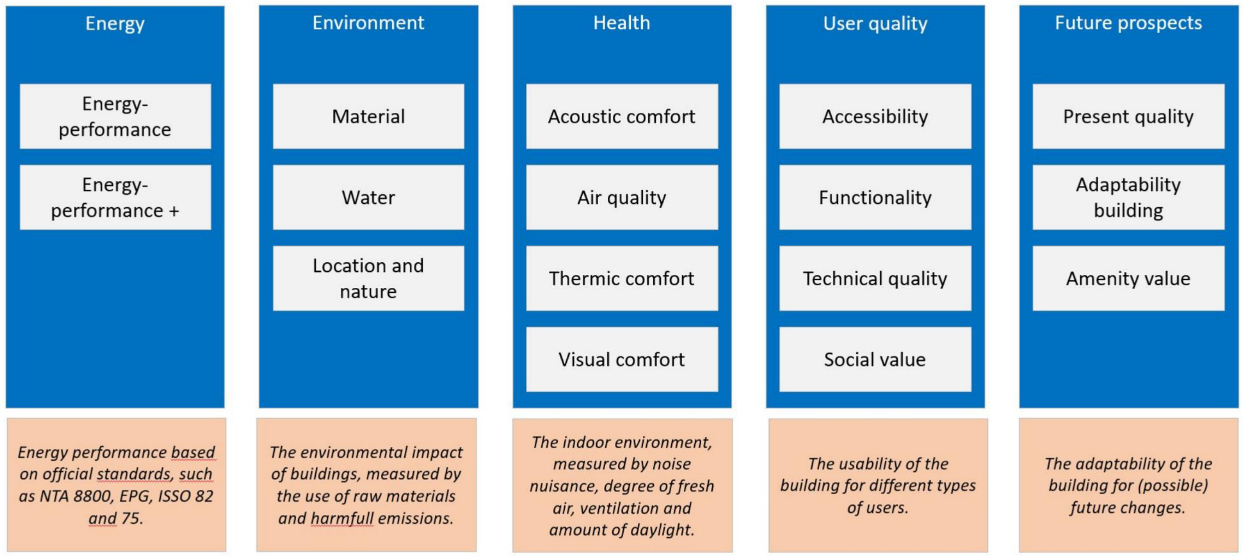

Figure 2. Sustainability measures.
Source: Adapted from W/E advisors, translated by authors

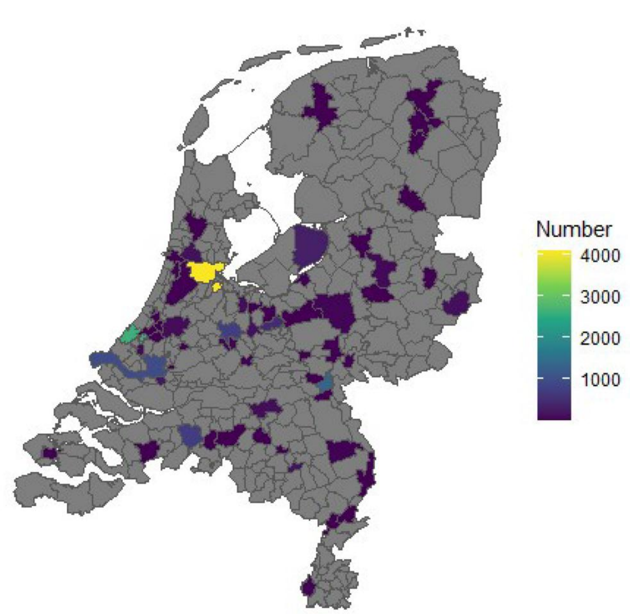

Figure 3. Spatial distribution of observations.
Source: Authors' own creation.

intercept; δ^t = the regression coefficient for time dummy period t; D_{it} = the time dummy for property i at period t; ${}_k$ = the regression coefficient for control variable k; c_{ik} = control variable k for real estate property i; β_l = the regression coefficient for sustainability score l; s_{il} = sustainability score l for real estate property i; ε_i^t= standard error for real estate property i at period t.

In this equation, real estate is considered as a bundle of characteristics. The price of the property can be explained as the sum of these characteristics. The main characteristics in above equation are time, control variables and sustainability. The aim is to determine the relationship between sustainability and price. This is achieved by including time and (other) control variables and, therefore, 'removing' other components that affect the price. Time is an important component as prices fluctuate through time. Property type is one of the most important control variables as different property types also have different price effects. Other variables, such as building age, floor area and location have proven to be good control variables in former studies (Eurostat, 2017; Porumb et al., 2020; Overbeek et al., 2023) and are, therefore, included in the model. In total, there are 25 versions of sustainability score *l*. These versions correspond to the scores and sub scores in Figure 2. The model with a breakdown of all variables is provided in Figure 4.

The rich source of sustainability scores implies many possible regression models to test the effect of sustainability on prices. It also involves two potential problems: multi-collinearity and complex/non-linear relationships. Multi- collinearity on 5 aspects is shown in Figure 5 and the possible existence of non-linear relationships between sustainability and prices is presented in Annex 1.

To solve the problem of non-linearity, so-called step functions, as explained by James et al. (2021), were introduced in the sustainability variables. In the step function process, the variables were split up into three parts, based on the percentage distributions of the score: 'low', 'medium' and 'high'.[4] Other solutions to tackle this issue would have been polynomial regression functions or regression splines (James et al., 2021). In our case (given the high number of to be tested scores), step functions performed better in terms of understanding, interpreting and reporting the results. Furthermore, polynomial regressions were performed, but did not led to different conclusions.

To solve the problem of multi-collinearity, the sustainability scores were entered into the basic regression model one at a time (so not simultaneously). Another solution would have been to include all scores simultaneously (within the same aggregation level) and control for multi-collinearity by adding interaction terms. This solution, however, in our case would lead to a confusing number of possibilities. To illustrate this: if we run a regression with interaction terms on the 5 main scores, it leads to 25 interaction terms (energy*environment, energy*health*user quality, and so on). In addition, we split the scores up

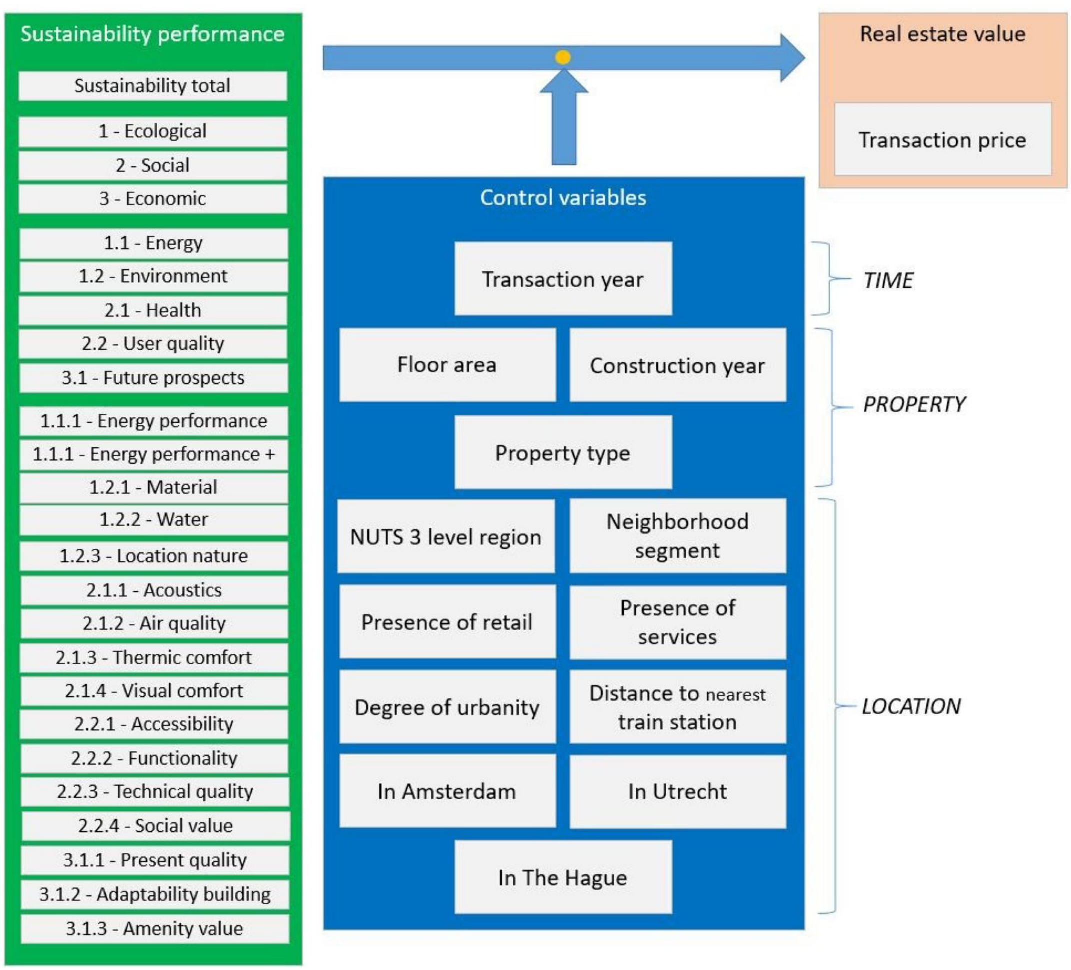

Figure 4. Conceptual model.
Source: Authors' own creation.

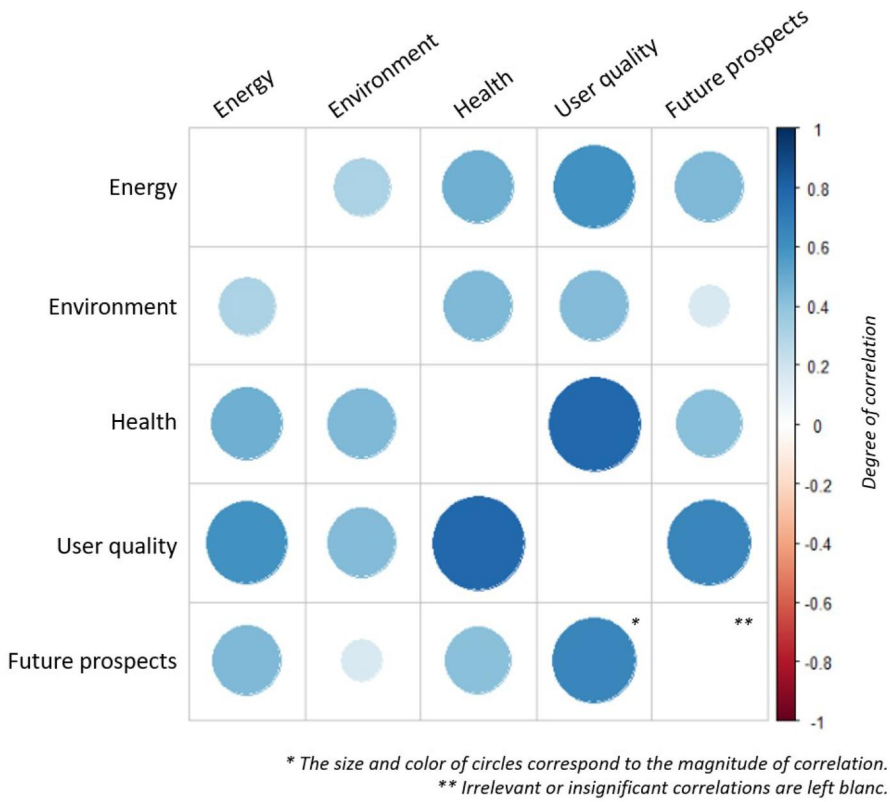

Figure 5. Multi-collinearity between sustainability scores.
Source: Authors' own creation.

into 3 categories (low, medium and high). In practice, we therefore deal with 15 scores (5*3) and possibly end up with 225 interaction terms (energy-low-*environment-medium, and so on). In our case, performing separate regressions worked better in terms of understanding, interpreting and reporting the results. Furthermore, interaction terms were tested, but did not lead to different conclusions.

3.3. Hedonic Imputation

The above regressions were troublesome to run per property type due to low observation numbers and limited variation in hedonic variables within property type strata. Therefore, all property types were pooled in one regression model and the differences in property types are captured in a 'property type'-dummy. To examine how a particular score affects the average value for different types of property when a particular sustainability score changes, we use a hedonic imputation approach. Hill et al. (2023), recently used a very similar approach to predict transaction prices if EPC recommendations were implemented. In this study, hedonic imputation is used to predict transaction prices if a sustainability score was increased.

In the first step, the regression model outcomes are used to predict (or impute) prices for all observations for the current sustainability state X. These imputations are then used to calculate the geometric mean corresponding to state X ($\widehat{\overline{P}}_X$, see equation 5[5]). Compared to the base regression model, presented in equation (1), the term z was added. This term denotes the level within the data: 'low', 'medium' or 'high'. This means that prices for state X are estimated per level. For instance, $P^t_{z=low,X}$ delivers estimates for all property with low sustainability scores at the current sustainability state X. Step 1 is denoted in equation (2).

$$\overline{\widehat{\ln P^t_{z,X}}} = \alpha + \sum_{t=1}^{T}\delta^t\overline{D_{z,t}} + \sum_{k=1}^{K}\beta_k\overline{c_{zk,X}} + \beta_l\overline{s_{zl,X}}, \quad (t = 0, \ldots, T), \tag{2}$$

In the second step, the model is used to calculate prices for state Y. In this step, the sustainability scores are fictitiously (one at a time) increased by 1 level (from 'low' to 'medium' or from 'medium to 'high'). For instance, observations with Energy level 'low' (state X) are fictitiously increased to level 'medium' (state Y). In another version, observations with Energy level 'medium' (state X) are fictitiously

Table 1. Descriptive statistics: low vs. high sustainability scores.

Property type	Sustainability segment	Value	Value / m^2	Construction age	Floor surface	Energy	User quality	Environment	Health	Future prospects
Industrial buildings	bottom 50%	€ 1,625,419	€ 1,058	31	4037	5.7	6.1	6.2	4.5	6.6
	upper 50%	€ 1,979,808	€ 1,524	18	1608	8.7	8.2	8.4	8.1	8.2
Office buildings	bottom 50%	€ 1,893,254	€ 15,769	91	338	4.9	7.1	4.9	5.0	7.3
	upper 50%	€ 1,823,631	€ 7,652	14	471	6.3	7.5	6.2	7.5	8.2
Retail buildings	bottom 50%	€ 1,559,008	€ 11,738	77	209	7.3	7.3	5.8	5.9	7.6
	upper 50%	€ 609,742	€ 6,116	18	141	7.7	8.2	7.4	6.5	7.6
Residential buildings	bottom 50%	€ 706,621	€ 4,475	22	190	6.2	7.0	5.9	6.4	6.1
	upper 50%	€ 584,269	€ 5,008	11	137	7.4	7.8	6.7	7.7	6.9

Source: Authors' own creation.

increased to level 'high' (state Y). Step 2 is denoted in equation (3). The difference with equation (2) is that all control variables $\overline{c_{zk,X}}$ are kept constant at state X and only the sustainability scores $\overline{s_{zl,Y}}$ have moved to state Y. All coefficients β remain the same as well as they are based on the same model (the regression is run only once on the original data).

$$\overline{\ln \widehat{P^t_{z,Y}}} = \alpha + \sum_{t=1}^{T} \delta^t \overline{D_{zt}} + \sum_{k=1}^{K} \beta_k \overline{c_{zk,X}} + \beta_l \overline{s_{zl,Y}}, (t = 0, \ldots, T), \tag{3}$$

After the second step, there are two versions of prices for the same set of observations: $\overline{\ln \widehat{P^t_{z,X}}}$ and $\overline{\ln \widehat{P^t_{z,Y}}}$. This allows us to determine the price effect of an energy increase from 'low' (state X) to 'medium' (state Y) for each property type. This price effect is determined by calculating a price ratio $I^P_{z,X\rightarrow Y}$ as denoted in equation (4). This method resembles a commonly used hedonic imputation price index method (CBS, 2022; Eurostat, 2013). Only here, instead of calculating price developments over time, X and Y represent different versions of calculations (and not different periods).

$$^{P}_{z,X\rightarrow Y} = \overline{\ln \widehat{P^t_{z,X}}} / \overline{\ln \widehat{P^t_{z,Y}}}, \tag{4}$$

At this point, the price difference – which is independent of time t - indicates the effect of a sustainability score increase by one level. Another step is necessary to standardise the ratio, because the levels of sustainability are allocated differently for each property type and each score. For example, Energy in office could have a 'low' and 'medium' level that corresponds to average scores 3 and 7. Health in retail could have very different levels as 'low' and 'medium' could correspond to average scores 5 and 6. A standardisation is performed by dividing price ratio $I^P_{z,X\rightarrow Y}$ by the corresponding sustainability ratio $I^S_{z,X\rightarrow Y}$. The result is a ratio of price and sustainability R_{PS}. The equation for standardisation is shown in equation (5).

$$R_{PS} = \frac{I^P_{z,X\rightarrow Y}}{I^S_{z,X\rightarrow Y}} = \frac{\overline{\ln \widehat{P^t_{z,X}}} / \overline{\ln \widehat{P^t_{z,Y}}}}{\overline{S^t_{z,X}} / \overline{S^t_{z,Y}}} \tag{5}$$

The results are presented in the next section.

4. Findings

4.1. Descriptive Statistics

Table 1 shows a distinction between real estate with high sustainability scores and low sustainability scores. This distinction is made by calculating the geometric mean of all five sustainability scores for each property (creating a total sustainability score). Every property below the mean is included in the lower group and every property above the mean is included in the higher group. The table shows some differences between the higher and lower class of sustainable real estate. An expected result is that younger buildings show on overage a higher degree of sustainability. An unexpected result is that for offices, retail and residential property, lower average prices were found in higher sustainability segments. Even if we correct for square metres, office and retail buildings still show lower prices in higher sustainability segments. These results indicate that a more sustainable property may be valued higher for these property types. Descriptive information is, however, not sufficient to base conclusions on as the average prices are not corrected for quality adding features. This is added in the regression analyses (section 4.3).

4.2 .Sustainability Over Time

Buildings are expected to improve in terms of sustainability over time. The relationship between the five sustainability scores and time is shown in Figure 6. On the left side, a linear relationship is assumed and on the right side, a flexible model with a second-degree polynomial (or quadratic) regression is plotted. Following the linear relationships, the figure supports the idea of a positive relationship.[6] The flexible model

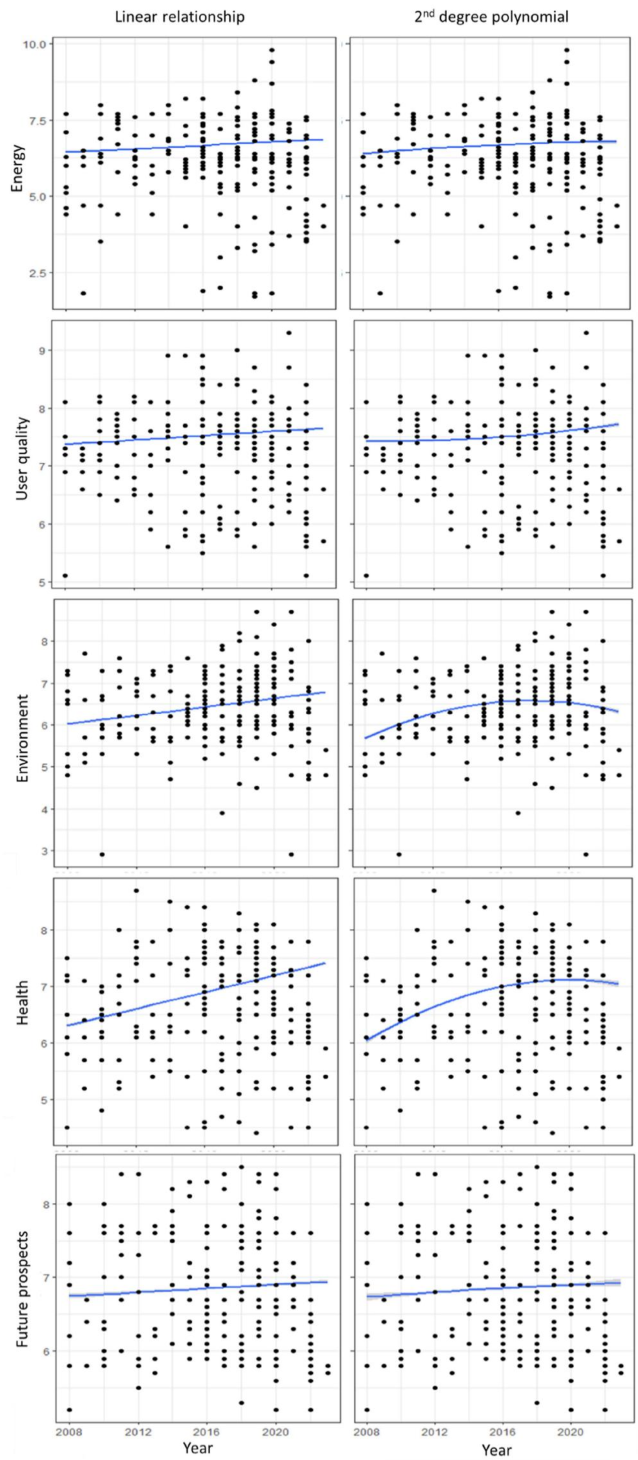

Figure 6. Sustainability scores over time.
Source: Authors' own creation.

shows that the relationship for some sustainability aspects is more complex. This is the case for User Quality, Environment and Health. For User Quality the relationship for the lower class is flatter and the positive relationship only becomes apparent in the upper class. For Environment and Health, the relationship is opposite. For the lower classes, there is a strong positive relationship. Towards the middle, it flattens and in the upper class the relationship is negative, indicating that more recently sold buildings perform worse regarding these sustainability scores. In general, the figure shows that time has a significant impact on the sustainability score. Moreover, time has a significant impact on the real estate prices (CBS,

Table 2. Regression results: control variables.

	(1) without sustainability		(2 - 26) + sustainability scores	
	Estimate (β)[1]	Significance	Estimate (β)[2]	Significance
Intercept	9,3***		8.7 : 13.2***	
Year	YES***		YES***	
Floor surface (log)	0,4***		0.4 : 0.4***	
Type: industry	1,6***		−0.9 : 2.3 .	
Type: community	6,0***		2.9 : 6.7***	
Type: office	2,2***		0.6 : 2.8***	
Type: education	2,2***		−0.4 : 2.2***	
Type: retail	0,5***		−1.7 : 1.1	
Type: house	1,7***		−0.8 : 2.1***	
Type: care	2,3***		−0.7 : 2.8***	
Construction year category	YES***		YES*	
NUTS3 region	YES***		YES***	
Neighbourhood segment	YES***		YES***	
Share servicesector	−2,7***		−3 : −0.3***	
Urbanity degree	−0,1***		−0.3 : 0.1	
Distance to trainstation	0,0***		0.0 : 0.1***	
In Amsterdam	−2,3***		−3.7 : −1.9***	
In The Hague	−0,8***		−2.4 : −0.3***	
In Utrecht	−0,4***		−0.5 : 0.4***	
Adjusted R2	0,73		0.73 : 0.75	
BIC	17.342		16,450 : 17,303	
Number of observations	10.652		10.652	

[1]Estimates are transformed by the natural logarithm. To relate the outcomes to actual prices, the estimates have to be exponentiated. For instance, the intercept of 9.3 equals a starting point of a price at € 10,938.
[2]For models 2-26, the range of coefficients (minimum - maximum) is presented.
*Significant at 95%-level.
**Significant at 99%-level.
***Significant at 99.9%-level.
Source: Authors' own creation.

2022). Therefore, time is entered in the regression model as a control variable.

4.3. Regression Analyses

Table 2 shows the results of different models related to the natural logarithm of transaction prices. The first model contains no sustainability scores. The explanatory variables already provide a solid explained variance with an adjusted R-squared of 0.73. In each model 2 to 26, a single sustainability scores is added one at a time. Table 2 shows only the corresponding control variables of these models. The estimates are summarised and a range (lowest: highest) of all models is presented in Table 2. Table 2 shows that the control variables remain stable and it shows that adding sustainability scores, slightly enhances both the adjusted R-squared and BIC.[7]

Table 3 shows the corresponding estimates for the sustainability scores. For presentation purposes, the estimates 'medium' and 'high' are placed alongside of each other instead of on top of each other. The level 'low' does not have estimates as this level is used as reference category. A notable result from this table is that a switch from low to medium is often accompanied by a negative movement of the transaction price. As we look at the category 'high', we see that the negative relationships have mostly been converted into positive relationships. Unfortunately, these results do not provide insight into the relationships per property type. The results in the next section will.

4.4. Hedonic Imputation

Table 4 shows the price changes that correspond to a change from level 'low' to level 'medium'. The scores are corrected for the level grades: a level increase from 'low' to 'medium' could correspond to an increase from 2 to 6 or from 4 to 5. The results are relative and should be interpreted as follows: a score increase of 1% corresponds to a price development as presented in the table. For example, the price development of 'sustainability total' in the top left corner of -3.68%, corresponds to a 'sustainability total' increase of 1%. The number between parentheses are one sides 95% confidence intervals.[8] The reported -3.68 could, therefore, be -0.13 or +0.13 within 95% certainty. For industry, confidence intervals could not be calculated due to too low numbers for 10-fold cross validation.

A very remarkable result is that most scores relate negatively to prices on the low end of sustainability. Although remarkable, it does correspond to the previous reported regression results (section 4.3). From the

Table 3. Regression results: sustainability scores.

	Medium		High	
	Estimate (β)	Significance	Estimate (β)	Significance
Sustainability total (2)	−0,8	***	−0,4	***
1 - Ecological (3)	−0,9	***	−0,3	***
2 - Social (4)	−0,6	***	0,0	
3 - Economic (5)	−0,3	***	0,0	
1.1 - Energy (6)	0,1	***	0,9	***
1.2 - Environment (7)	−1,2	***	−0,7	***
2.1 - Health (8)	−0,9	***	−0,3	***
2.2 - User quality (9)	−0,4	***	0,3	***
3.1 - Future prospects (10)	−0,3	***	0,0	
1.1.1 - Energy performance (11)	0,0		0,8	***
1.1.1 - Energy performance + (12)	0,2	***	0,4	***
1.2.1 - Material (13)	−0,6	***	−0,3	***
1.2.2 - Water (14)	−0,2	***	0,4	***
1.2.3 - Location nature (15)	0,4	***	0,8	***
2.1.1 - Acoustics (16)	−0,8	***	−0,4	***
2.1.2 - Air quality (17)	−0,6	***	0,4	***
2.1.3 - Thermic comfort (18)	0,4	***	0,6	***
2.1.4 - Visual comfort (19)	−0,6	***	−0,7	***
2.2.1 - Accessibility (20)	0,3	***	1,0	***
2.2.2 - Functionality (21)	−0,8	***	0,3	***
2.2.3 - Technical quality (22)	−0,4	***	−0,3	***
2.2.4 - Social value (23)	0,2	***	0,4	***
3.1.1 - Present quality (24)	0,3	***	0,6	***
3.1.2 - Adaptability building (25)	−0,1	**	0,2	***
3.1.3 - Amenity value (26)	−1,3	***	−0,7	***

Source: Authors' own creation.

Table 4. Hedonic imputation results: lower segment price changes per property type.

	Residential	Office	Industry	Retail
Sustainability total	−3.68 (0.13)	−2.38 (0.50)	−4.52 (.)	−7.01 (1.67)
1 - Ecological	−3.63 (0.16)	−2.28 (0.31)	−5.06 (.)	−5.27 (1.3)
2 - Social	−2.94 (0.22)	−1.97 (0.31)	−2.31 (.)	−6.63 (1.66)
3 - Economic	−2.05 (0.27)	−1.62 (0.39)	−1.4 (.)	−1.57 (0.88)
1.1 - Energy	0.89 (0.23)	0.52 (0.14)	2.89 (.)	3.17 (1.35)
1.2 - Environment	−3.77 (0.24)	−2.91 (0.31)	−2.83 (.)	−3.76 (0.86)
2.1 - Health	−2.48 (0.09)	−1.17 (0.25)	−2.05 (.)	−5.99 (1.12)
2.2 - User quality	−2.94 (0.40)	−6.29 (2.11)	−2.22 (.)	−3.48 (0.86)
3.1 - Future prospects	−2.05 (0.34)	−1.62 (0.39)	−1.4 (.)	−1.57 (1.46)
1.1.1 - Energy performance	−0.12 (0.10)	−0.09 (0.08)	−0.31 (.)	−0.33 (0.32)
1.1.1 - Energy performance +	1.18 (0.29)	0.75 (0.24)	. (.)	2.39 (1.84)
1.2.1 - Material	−1.2 (0.10)	−4.85 (0.93)	−2.41 (.)	0 (1.33)
1.2.2 - Water	−4.93 (1.07)	−0.37 (0.06)	−0.87 (.)	−0.6 (0.09)
1.2.3 - Location nature	1.86 (0.34)	0.92 (0.23)	27.11 (.)	1.26 (0.24)
2.1.1 - Acoustics	−1.26 (0.10)	−0.28 (0.07)	. (.)	−1.31 (0.21)
2.1.2 - Air quality	−1.91 (0.27)	−1.62 (0.58)	−1.03 (.)	−8.19 (11.67)
2.1.3 - Thermic comfort	2.74 (0.58)	0.86 (0.47)	1.09 (.)	3.27 (1.39)
2.1.4 - Visual comfort	−1.41 (0.09)	−2.55 (0.21)	−5.4 (.)	−2.46 (1.33)
2.2.1 - Accessibility	1.28 (0.26)	1.46 (0.40)	. (.)	3.62 (0.69)
2.2.2 - Functionality	−13.54 (0.77)	−4.65 (1.57)	−9.52 (.)	−6.42 (1.53)
2.2.3 - Technical quality	−0.99 (0.09)	−0.74 (0.10)	. (.)	−2.07 (0.53)
2.2.4 - Social value	2.14 (0.79)	1.64 (1.47)	0.33 (.)	1.29 (0.47)
3.1.1 - Present quality	0.78 (0.15)	0.5 (0.11)	1.05 (.)	5.05 (2.53)
3.1.2 - Adaptability building	−0.83 (0.35)	−2.31 (1.58)	−1.01 (.)	−1.34 (0.64)
3.1.3 - Amenity value	−6.17 (0.32)	−3.24 (0.19)	−2.62 (.)	−11.96 (5.04)

Source: Authors' own creation.

5 aggregate dimensions of sustainability, 'Energy' is the only one that shows price increases.

Table 5 shows the price changes that correspond to a change from level 'medium' to level 'high'. It is immediately noticeable that nearly all sustainability scores now show a positive relationship with transaction prices.

5. Discussion and Conclusions

5.1. The Effects of Sustainability Measures on Real Estate Prices

In this study, the aim was to investigate the relationship between sustainability measures and real estate transaction prices for commercial real estate. The

Table 5. Hedonic imputation results: higher segment price changes per property type.

	Residential	Office	Industry	Retail
Sustainability total	4.56 (0.84)	17.31 (16.16)	1.2 (.)	62.62 (24.15)
1 - Ecological	8.41 (0.70)	10.3 (3.21)	2.62 (.)	27.4 (1.57)
2 - Social	14 (2.02)	19.22 (6.47)	2.68 (.)	7.02 (.)
3 - Economic	3.8 (0.61)	19.25 (.)	4.77 (.)	10.2 (1.98)
1.1 - Energy	4.6 (0.86)	15.28 (6.32)	2.54 (.)	86.1 (63.47)
1.2 - Environment	4.97 (0.64)	7.37 (3.44)	4.51 (.)	8.4 (1.15)
2.1 - Health	6 (1.16)	31.17 (14.78)	1.37 (.)	39.88 (6.35)
2.2 - User quality	13.17 (2.57)	10.18 (5.03)	4.4 (.)	11.32 (.)
3.1 - Future prospects	3.8 (1.23)	19.25 (.)	4.77 (.)	10.2 (2.11)
1.1.1 - Energy performance	4.94 (0.58)	11.73 (3.16)	2.39 (.)	16.51 (.)
1.1.1 - Energy performance +	1.32 (0.36)	1.62 (0.44)	. (.)	3.54 (0.72)
1.2.1 - Material	1.9 (0.23)	1.67 (0.52)	2.08 (.)	2.63 (0.78)
1.2.2 - Water	8.25 (0.90)	8.71 (2.38)	1.31 (.)	16.93 (3.07)
1.2.3 - Location nature	3.8 (0.77)	3.7 (1.25)	0.69 (.)	21.38 (7.39)
2.1.1 - Acoustics	2.94 (0.38)	3.67 (1.15)	. (.)	. (.)
2.1.2 - Air quality	23.64 (2.75)	16.17 (4.63)	1.86 (.)	39.99 (13.74)
2.1.3 - Thermic comfort	1.46 (0.46)	2.47 (0.57)	0.7 (.)	2.8 (0.94)
2.1.4 - Visual comfort	−0.31 (0.30)	−0.45 (0.45)	−0.3 (.)	−1.01 (1.99)
2.2.1 - Accessibility	3.24 (0.63)	4.2 (1.03)	. (.)	14.74 (.)
2.2.2 - Functionality	17.4 (1.09)	60.65 (14.27)	9.69 (.)	. (.)
2.2.3 - Technical quality	. (.)	1.47 (1.35)	. (.)	2.86 (1.47)
2.2.4 - Social value	3.5 (1.53)	3.06 (1.11)	. (.)	. (.)
3.1.1 - Present quality	1.02 (0.45)	. (.)	1.32 (.)	1.79 (0.76)
3.1.2 - Adaptability building	2.97 (0.43)	10.92 (2.01)	. (.)	6.56 (2.90)
3.1.3 - Amenity value	7.26 (0.45)	32.59 (.)	7.62 (.)	14.08 (0.88)

Source: Authors' own creation.

results show that this relationship is complex. Whether there is a positive or negative effect on prices, varies between specific sustainability measures and property types. The effect in the lower sustainability segment also differs from the effect in the higher sustainability segment. Of the five main sustainability scores, 'energy' is the one that shows a consistent positive effect for all property types and in both the low and high segment. This is in line with previous studies that already show a positive relationship between energy efficiency and property value (Eichholtz et al., 2010; Kok & Jennen, 2010; Fuerst & McAllister, 2011b; Chegut et al., 2014; Devine & Kok, 2015; Pride et al., 2017; Aroul & Rodriguez, 2017; Cajias et al., 2019; Holtermans & Kok, 2019; Mangialardo et al., 2019; Mironiuc et al., 2021; Lambourne, 2022; Overbeek et al., 2023). The other sustainability scores, for which the price effects have not been studied before, show mostly negative relations in the low sustainability segment. This indicates that for most sustainability measures, there is no clear financial incentive to start investing in sustainability.

Referring back to the barriers in the development of sustainability, these results indicate that is it is not likely that the barriers will be broken because of financial benefits. An intervention of an outside actor, most likely the government, is very welcome when it comes to increasing sustainability other than energy efficiency. A first step would be creating more awareness on sustainability other than energy efficiency by consistently measuring these aspects. Based on a study on rating tools, Warren-Myers and Reed (2010) argue that government input is needed here as well to achieve real change in the real estate sector.

Although this study provides new insights on the various effects of sustainability (in a broad sense) on transaction prices, it should be noted that there are some studies that show similar, negative price effects. Zheng et al. (2012), for instance, found that 'buildings that score high on the green index sell for a price premium at the presale stage, but they are subsequently leased or resold for a price discount'. This result not only shows that negative price effects also occur elsewhere, but also shows that the relationship is complex: there is a positive effect at presale, but a negative effect after that. Yoshida and Sugiura (2015) and Evangelista et al. (2022) found similar negative price effects. They found, like this study, that price discounts typically occur at the lowest quantiles of the price distribution. Zheng et al. (2012) and Yoshida and Sugiura (2015) also provide explanations: green technologies can reduce user costs, but can also increase user costs. For instance, replacement costs of sustainable materials could be higher. Another example is that a central air conditioning system that is sustainable given the air quality, consumes more electricity and thus is less sustainable in another sense. All in all, sustainability sometimes induces higher life-cycle use costs.

5.1.1. Limitations and Further Research

Although this study is one of the first attempts to grasp the effect of the broad concept of sustainability on transaction prices, it has a few limitations.

First, the results could be distorted by scarcity of real estate in the Netherlands. As a study of Colliers (2023) recently showed, rental prices for housing do not tend to be lower for houses with a low energy label. The measured average rent was even higher for low energy labels. They suggest that this may be caused by scarcity in the Dutch market: investors will retrieve high income anyway, so there is no incentive to increase sustainability. A follow up study on transaction prices could be conducted on whether the scarcity effect could also have distorted the results of this study.

Second, a possible explanation is that sustainability measures could increase user costs and, therefore, may not lead to a price increase. Further research on this possible explanation is recommended, for instance, by measuring user costs alongside sustainability measures and analysing the relationship between the two.

Notes

1. The definition for commercial real estate, that is followed in this study, is provided by Eurostat,(2017, p. 32): commercial property is … "all property other than owner-occupied housing and property used in non-market activity". This definition includes rental housing.
2. The reason for conducting this study in the Netherlands, is as follows: the data that is used in this study, is retrieved from statistics Netherlands. Statistics Netherlands has spent many years on processing commercial real estate data and improving the data quality. Given that the data is cleaned up and that it includes transaction prices and sustainability scores, makes it a suitable case for this study.
3. A difference-in-difference approach was also considered and pursued, but due to a lack of a solid panel data structure, this approach was not feasible.
4. Four and five categories were also tested, but given the number of observations and variation in the scores, three categories had the best performance. The percentage distribution for each sustainability score was examined in order to distribute steps according to natural break points.
5. In practice, the prices are imputed on the level of individual observations. After that, the geometric mean is calculated to retrieve $\overline{\ln \widehat{P^t_{i,X}}}$. This bypasses the obstacle of averaging dummies.
6. 95% confidence intervals are plotted as well, but could be too small to observe. This, however, does indicate a good fit of the models on the data.
7. Next to R^2, BIC is often used to evaluate regression models. BIC (Bayesian Information Criteria) is a variant of AIC (Akaike Information Criteria) with a stronger penalty for extra variables in the model. For BIC applies: lower indicates a better model accuracy.
8. The margins are calculated with a 10-fold cross-validation as described in James et al., (2021).

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