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The impact of building location on green certification price premiums: Evidence from three European countries

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ABSTRACT

Green building certification has gained global prominence in the wake of the recent calls for ensuring the sustainable development of expanding urban areas. This trend rooted in the fact that buildings are among the main sources of energy consumption and CO2 emissions. Green certification therefore emerged in response to sustainability concerns throughout the building sector. Nonetheless, the significant costs required by green investments have elicited scholars' attention, in an attempt to determine if the benefits of green certification outweigh its costs. This study uses a proprietary data-set of office building transactions from three major European countries - Finland, France, and Germany - in order to analyze the price premium of green certification over the 2010–2015 period. Considering the increasing demand for certification in the European Union (EU) after 2010, it is expected that green office buildings would sell at higher prices relative to non-green buildings. Empirical tests suggest that office buildings with green certification have a 19 percent higher price relative to non-certified buildings. Further, the study aims to assess whether the premium varies with the location of the green buildings within the urban area. Given the price premium brought by a central location - irrespective of green certification - it is expected that the price premium of green investments would incrementally increase in non-central locations. The distance variable is hand-constructed based on geocoding all properties in the dataset - empirical results indicate that the green certification price premium incrementally increases by 10.5 percent for 1-km distance from the city center. Further tests show that the distance effect becomes insignificant in both (i) large cities and (ii) cities of under 200,000 inhabitants. In these two contingencies, the price premium associated with central locations is reduced - which also diminishes the relevance of the green buildings' location. The empirical results are robust to eliminating 2010 and 2011 from the sample and to employing a propensity score matching approach, aimed at increasing the similarity of the treatment and control groups. This paper adds to the rising literature on the topic of green buildings, as it is the first international study to assess the price impact of green certification as a function of office building location.

1. Introduction

Climate change is one of the most important globally-recognized contemporaneous problems, which renders sustainable development a top-priority on the agendas of governments worldwide. In the coming years, the global level of energy consumption will continue to increase based on the economic development and population growth patterns (Bilgen, 2014; Schandl et al., 2016; Balaban and de Oliveira, 2017). Decision makers in the European Union (EU) are increasingly focusing on reducing energy consumption and greenhouse gas emissions by up to 80 percent of the current levels by 2050 (European Commission, 2011). To reach this goal, it is vital to understand what are the main sources of energy consumption and the major worldwide trends in the energy consumption process. In 2014, buildings accounted for 40 percent of all energy consumption - a large increase compared to 1950, when real estate was responsible for less than 30 percent. Moreover, buildings are responsible for producing 6 percent of the

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worldwide greenhouse gas emissions (United States Environmental Protection Agency, 2016) and 36 percent of the total CO2 emissions in the EU (United Nations, 2009). A responsible development of the building sector - as an integral part of the urban sector - is of paramount importance on the way to a greener economy and healthier cities (de Oliveira et al., 2013). One of the regulatory and market responses is the adoption and development of the green building certification, a system aimed at reducing the negative environmental impact (Zhang et al., 2018). Concurrently, green investment informs developers and other stakeholders about the energy performance of the real estate properties (Ismaeel, 2019).

In spite of clear indications of societal benefits,[1] investments in green developments are nonetheless limited due to their high construction costs (Kats et al., 2003; Zhang et al., 2015; Soetanto et al., 2014).[2] Given the investment required to obtain a certification, the majority of green building developments are in the commercial and office sectors.[3] Office buildings especially are expected to cover the additional costs of certification, given the benefits that companies anticipate to extract from being located in environmentally friendly buildings (Fombrun and Shanley, 1990; Zhang et al., 2018).[4] As the demand for certified buildings increases, the same is expected of their rents or prices (Fuerst and McAllister, 2011a). To date, given the fundamental importance of assessing the economic viability of green certification (Zhang et al., 2018), a significant number of academic studies have investigated the price premiums associated with the energy efficiency certificates. However, most of the empirical evidence is focused on North America and presents single-country analyses.[5]

This paper expands the fast developing literature on green building certification (Li et al., 2020) by using a proprietary dataset. Drawing on the DTZ Research Institute database offers the unique possibility to study the impact of green certification in an international setting. More specifically, the study focuses on the price premiums of green office buildings in three major EU countries - France, Finland and Germany - between 2010 and 2015. The EU office building market is chosen due to its distinct characteristics. Green building developments in Europe are relatively recent; the pace of green building certification across Europe has intensified, as can be observed from the new projects that have been developed in the last five years. An increasing share of new buildings is green and the trend is likely to be maintained in the next years, since about 35 percent of the buildings in the EU are over 50 years old (European Parliament, 2012) - replacing them will likely equate with a wide spread of green buildings in the future. The analyses in this study are therefore likely to bring a significant contribution to the academic literature and to be of relevance for the commercial green building development in Europe. Furthermore, this paper not only focuses on a new setting which is characterized by the fast development of green buildings, but, unlike the previous studies, it also analyzes the impact of *location* (distance from the city center) on the buildings' price premiums.

The analysis is driven by the fact that research on the US market finds green buildings to be located predominantly and disproportionally in prime locations (Braun et al., 2014). Nonetheless, the buildings that are located in the central business district (CBD) already bring a price premium for their prime location. Given this, it is not clear if the additional premium brought by the green certification is indeed material. It is therefore expected that a green premium would be incrementally larger when buildings are located farther from the city center - in this contingency, the green certification would more likely constitute a differentiation characteristic.

Overall, the empirical inquiry of this paper is particularly important, given the recent interest of international policy makers (Olubunmi et al., 2016) and of the European Commission for the energy performance of non-residential buildings (Triple E Consulting, 2014). The Commission and the European Parliament are interested in increasing the number of green office buildings in the countries of the EU (European Parliament, 2018) and this paper offers novel evidence on the financial incentives associated with green certification. Moreover, relative to extant research, the analysis of the price premiums for office buildings' green certification is performed by using proprietary data from an *international* setting. Therefore, given the recent efforts made by regulators to encourage green building certification throughout the countries of the EU (European Parliament, 2018), this research is both timely and relevant.

Lastly, and most important, the study is, to the best of the authors' knowledge, the only one to analyze the impact of green buildings' spatial distribution on price premiums. By understanding the financial benefits brought by the green certification, concurrent with the choice of building location, developers can thus obtain higher returns on investment. This study therefore provides empirical proof which can be used by developers in drafting feasibility projects for new constructions.

The rest of the study is organized as follows. First, the emergence of green building certification in Europe is discussed, following by a review of the relevant literature and the development of hypotheses. Further, the choice of methodology is discussed and the empirical results are interpreted. Finally, the study presents overall conclusions.

1.1. Emergence of green real estate certification

Over the past decades, sustainability has become an important topic, both for researchers and professionals. Greenhouse gas emissions have become not only a general public concern, but also an incentive to develop proper technologies in the construction sector. The International Energy Agency (IEA) estimates that buildings will remain the most important energy-use sector by 2050, with a 50 percent increase in the global energy consumption if no action is taken to increase construction energy efficiency (IEA,

[1] Research suggests that buildings with green certification could reduce greenhouse gas emissions by 22 percent (Suh et al., 2014). Moreover, retrofitting the existing buildings accounts for a 57 percent drop in energy consumption (Zhou et al., 2016).

[2] To assess its viability, recent research developed frameworks for energy performance contracting (EPC) (Zhang et al., 2015; Yuan et al., 2016).

[3] The early studies in this literature stream mostly focused on the residential sector - for example Gilmer (1989) observed a positive impact of energy labels in the US market.

[4] A green building certification is similar to a brand, since it increases the potential tenants' willingness to rent, especially when they are supportive of higher levels of eco-friendliness (Jang et al., 2018).

[5] Findings suggest that the incremental cost for a LEED certification on an office building is around 2 percent for Gold and Silver and 6.5 percent for Platinum (Kats et al., 2003), for Green Star certification: 3 percent - 5 percent for 5 Star and 9 percent - 11 percent for 6 Star (Matthiesen and Morris, 2004), HK-BEAM certification brings a 1.3 percent for Gold and 3.2 percent for Platinum (Construction Industry Institute, 2008), while BREEAM certification is associated with an incremental cost of 0.8 percent for Excellent and 9.8 percent for Outstanding (TargetZero, 2012). Miller et al. (2008) find a price premium of 9.9 percent for LEED certified buildings and 5.3 percent for Energy Star. Fuerst and McAllister (2009) find a sale price premium of 31 percent for Energy Star certified buildings and 35 percent for the ones with LEED certification. Regarding the rental premium, the authors have identified a rental premium between 4 and 5 percent. Eichholtz et al. (2010) study 10,000 commercial buildings with LEED and/or Energy Star labels and document an increase in selling prices of 16 percent for certified buildings. Nonetheless, no rent and price premiums for LEED certifications were found. The research further assessed a key dimension of green building development - the users' willingness to pay (Liu et al., 2019). Jang et al. (2018) document an increased willingness of the tenants to rent space in a building with a green certification, irrespective of the certification grade.

2013). This situation creates pressure to develop public policies as well as adequate retrofitting and higher energy efficiency strategies. One type of regulatory and market response to this situation is the adoption and development of green building certification, which inform building owners and all stakeholders about the energy performance of the real estate property.

In Europe, the Energy Performance of Building Directive (EPBD) of 2010 - revised in 2018 - requires all new buildings to be nearly zero-energy by the end of 2020. In the same vein, the EU Building Stock Observatory was proposed to monitor the energy performance of constructions across Europe. This database is aimed at presenting the level of energy efficiency in buildings both across Europe and in individual EU Member States.

At the professional and private level, only a few sustainability measurement systems prevailed: BREEAM, DGNB, HQE, LEED. Specifically, The Building Research Establishment from the UK developed an instrument called Building Research Establishment Environmental Assessment (BREEAM), which issued more than 569,000 certificates in 83 countries. In Germany, in early 1990s, The German Council for Sustainable Buildings started to develop its own product, i.e. Deutsche Gesellschaft fur Nachhaltiges Bauen (DGNB), - which certified buildings in more than 40 countries. In France, Association pour la Haute Qualite Environnementale (ASSOHQE) developed Haute Qualite Environnementale (HQE). This French certification awarded to building construction, management and urban planning projects is present in more than 24 countries. In the US, the Green Building Council developed a product called Leadership in Energy and Environmental Design System (LEED) which is present in over 165 countries and territories. Also, a voluntary scheme of the U.S. Environmental Protection Agency (EPA) is developing the ENERGY STAR certification for Commercial Buildings and Industrial Plants.

In conclusion, a prevalent interest for the energy efficiency of buildings determined the creation of green certification institutions. Moreover, in 1999, there were 8 countries which founded the World Green Building Council (WorldGBC). Since then, the number of national green building councils expanded to more than 93, covering more than 25,000 member organizations. The concurrent development of green certifications resulted in the WorldGBC reporting a current stock of 1 billion square meters of green registered space worldwide.[6]

Energy efficiency of office buildings impacts the tenants' and building owners' budgets. Given that energy consumption represents 30 percent of the operating expenses of a normal office building (Eichholtz et al., 2010), any saving will have a positive impact on the budget of the developer. Between 2008 and 2012, the number of BREEAM certification schemes for commercial buildings doubled, from 8000 to 16,000. In a similar manner, HQE (a green certification council in France) increased the number of certifications from 13 in 2005 to more than 341 in 2013.[7] Concurrently, DGNB certification went up to covering more than 530 projects and continues to expand. Fig. 1, which was obtained from DGNB, displays the monotonic increase in green certifications as reported by the DGNB certification council. These numbers suggest an increasing interest in green buildings in the commercial sector. Given the development of green certifications, it only makes sense to root the empirical analysis in its obvious economic implications. Moreover, considering that the willingness of stakeholders to pay for green certification increases with their knowledge of the technologies subject to certification (Ofek and Portnov, 2019), a worldwide development of green investments is likely to result in ever increasing benefits of the environmental-friendly practices (Ahmad et al., 2019; Zameer et al., 2020).

1.2. Related literature and development of hypotheses

The discussion concerning the potential benefits of building characteristics needs to start from the analysis of potentially reduced building, holding, occupational and operational costs for the considered characteristics. Previous research analyzed the existence of potential construction cost premiums brought by green certification. Studies by Kats et al. (2003), Berry (2007) and Matthiesen and Morris (2007) find extremely small (around 2 percent) or insignificant cost premiums for green buildings (Hershfield, 2005; Construction and Council, 2006). Overall, this entails significantly higher construction costs for green buildings.[8] A benefit of green certification consists in smaller holding costs that stem from higher occupancy, tenant retention and reduced energy costs (Quigley, 1991). Kats et al. (2003) find that the net present value of the reduced holding costs is sufficient to cover the higher construction costs. Fuerst and McAllister (2009) focus on the effect of certification on the rate of occupancy and document that, in comparison with non-certified buildings, green office buildings are more likely to be occupied.

Recently, academic literature endeavored to determine if green certification brings a selling price premium. Aside from the aforementioned benefits of certification, a potential reason for the existence of price premiums is enhanced corporate reputation. According to previous literature, if seen as an act of social responsibility, residing in green buildings can boost reputation (Fombrun and Shanley, 1990). Firms with better reputations have benefits in attracting investors (Milgrom and Roberts, 1986), charging higher price premiums (Klein and Leffler, 1981) and more talented employees (Turban and Greening, 1997). Moreover, these firms benefit from less intrusion from governmental organizations (Lyon and Maxwell, 2011). Tables 1 and 2 illustrate the academic studies which assesses the existence of rent or sale premiums for residential or commercial buildings.

This literature emerged due to the scarce evidence of a certification premium (Berry, 2007). Fuerst and McAllister (2011a) document a sale price premium of 31 percent for Energy Star certified buildings and 35 percent for LEED certified. Miller et al. (2008) find a price premium of 9.9 percent for LEED certified buildings and 5.3 percent for Energy Star while Wiley et al. (2010) document a 15–18 percent rental premium for LEED and 7–9 percent premium for Energy Star. Occupancy rates were also 10–11 percent higher for Energy Star and 16–18 percent for LEED certified. Regarding sale prices, certified properties sell at a 30[*start*][*end*][*start*][*end*][*start*][*end*] 129/ft2 price premium versus comparable properties. In slight contrast, Eichholtz et al. (2010) show an increase of 3 percent in rent and 16 percent in selling price for Energy Star green certificates, but *no rent and price premium* for LEED certificates. Using a sample of 123 commercial properties, another paper Das et al. (2011) finds that green commercial buildings receive a rental premium of 2.4 percent in a down-market and of 0.1 percent in a growing market. Based on a sample of more that 5000 commercial leasing transactions and 4500 sales transactions in London, Chegut et al. (2011) observed that buildings with green certificates lease for 21 percent more than non-green buildings and are sold at a price premium of around 26 percent. Considering an analysis of 1100 rental transactions in

[6] The council used multiple rating systems to identify "green" constructions.

[7] Moreover, in China, 3-Star represents one of the most common, fast-developing certification systems (Zou, 2019).

[8] Other studies, such as Li et al. (2019), do not limit their analysis at a price or rent premium, but perform a life-cycle analysis of the green certification.

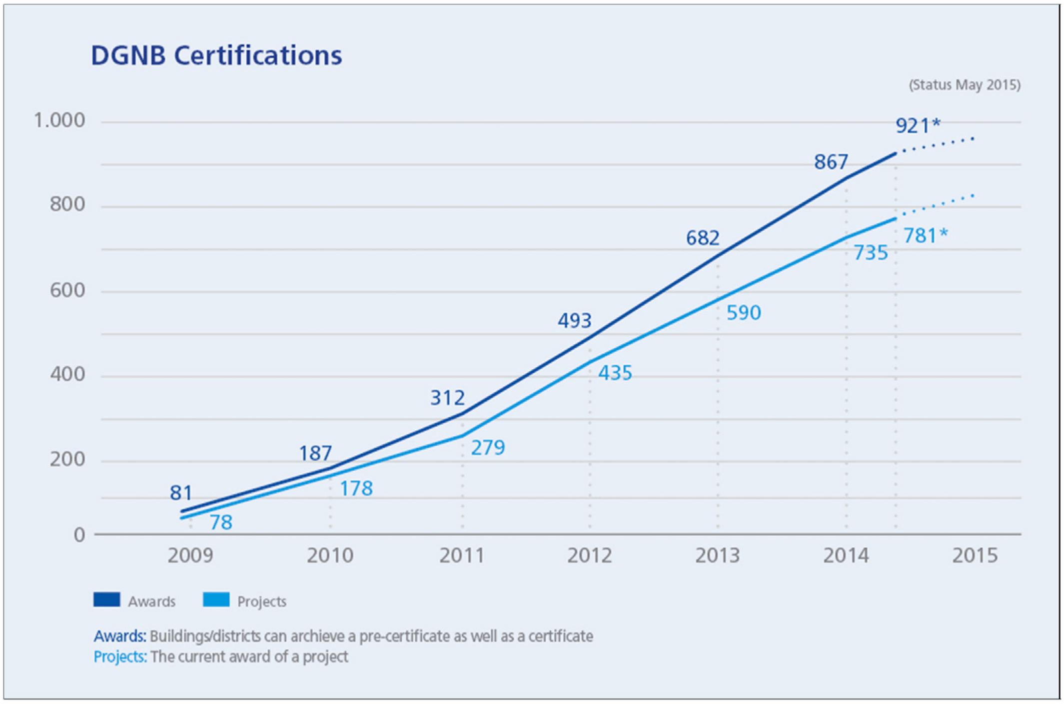

Fig. 1. A depiction of the steady increase in green building certification after 2010. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
An overview of the literature on the impact of green certification for *commercial* buildings.

Study	Country	Main results
Wiley et al. (2010)	US	Rental premium is between 7 and 17 percent. The occupancy rate is 10–18 percent higher for green certified properties
Eichholtz et al. (2010)	US	Certified buildings receive around 3 percent rental premium and 16 percent price premium.
Das et al. (2011)	US	Green commercial buildings receive 2.4 percent rental premium in down-market and 0.1 percent in growing market.
Fuerst and McAllister (2011a)	US	The green buildings receive a rental premium between 4 and 5 percent and around 25–26 percent sale price premium.
Chegut et al. (2011)	UK	21 percent rental premium and 26 percent price premium for certification. The green premium decreasing with the overall number of green buildings.
Fuerst and McAllister (2011b)	UK	No significant impact of energy ratings on market value of commercial office space.
Kok and Jennen (2012)	Nederlands	Commercial green buildings are traded with a 6.5 percent discount
Reichardt et al. (2012)	US	Energy efficient commercial buildings receive an average rent premium between 2.5 and 2.9 percent. Also, positive relationship with the occupancy rate.
Eichholtz et al. (2010)	US	The green premium is 3 percent for rental rates and 8 percent for effective rents. There is a sales price premium at 13 percent.
Chegut et al. (2014)	UK	The green premium in London is 19.7 percent for rents and 14.7 percent for transactions (BREEAM certification vs non-certification).
Devine and Kok (2015)	US, Canada	Higher occupancy rate for certified buildings. Price rental premium 9–10 percent buildings class A and B vs class C. Larger buildings receive higher rents, doubling building size increases rents with 8. Rent concession 11 percent non-certified vs 7 percent certified (brand effect).
An and Pivo (2015)	US	Negative association between commercial building green certification and commercial mortgage default.
Holtermans and Kok (2017)	US	Rental premium of 2.2 percent and a price premium of 10.1 percent for certified buildings

The Netherlands, Kok and Jennen (2012) provide evidence that an office building without green certification achieves a 6.5 percent lower rent as compared to other similar buildings certified as green. Chegut et al. (2016) document a premium for commercial certified buildings at 19.7 percent for rental transactions and 14.7 percent for sales transactions in London. Their data set consisted of 1149 rental transactions (of which 64 rental transactions with BREEAM certification) and 2103 observations with sales transactions (68 with BREEAM certification). Based on a data set of 148 buildings in Canada and 143 in USA, Devine and Kok (2015) find that the building occupancy rate is 8.5 percent higher for LEED certified buildings (Canadian sample) and 4–9 percent higher for LEED/Energy Star certification (US sample).

Recent studies also consider the impact of certification on riskiness. An and Pivo (2015) find that, based on the analysis of 22,813 loans, there is a negative correlation between green certification (LEED and ENERGY STAR) for commercial buildings and commercial mortgage default. Holtermans and Kok (2017) analyzed a rental sample of 27,451 office buildings (3012 certified) and a transaction sample that included a total of 10,454 office buildings (817 certified) and found a rental premium of 2.2 percent (Energy Star or LEED certified buildings compared to non-certified buildings) and price premium of 10.1 percent. There are also academic studies that didn't find a positive effect of green certificates. Fuerst

Table 2
An overview of the literature on the impact of green certification for *residential* buildings.

Study	Country	Main results
Gilmer (1989)	USA	Energy efficient labels shorten search times
Australian Bureau of Statistics (2008)	Australia	House price increasing 1.9 percent in 2006 for each increase in efficiency scale
Zheng et al. (2012)	China	Green buildings receive an initial sales price premium. Reselling is done with a price discount.
Caijas and Piazolo (2012)	Germany	1 percent improvement in energy efficiency increases rents with 0.08 percent and market value of the property with 0.45 percent
Kahn and Kok (2011)	USA	Green buildings obtain 9 percent price premium.
Yuan et al. (2016)	Japan	Buildings certified as green receive a price premium of approximately 5.5 percent
Amecke (2012)	Germany	There is a limited effect in acquiring decision of the energy performance certificate.
Hyland et al. (2013)	Ireland	An energy rated properties received 9,3 percent premium vs D energy rating.
Chegut et al. (2016)	Nederlands	6.3 percent premium a dwelling A label vs similar property with C label and 2 percent in comparison with homes having a B level certification.
Taltavull et al. (2017)	Romania	Average 3.5 percent price premium for apartments in retrofitted buildings

and McAllister (2011c) found that there was no significant impact of energy ratings on the market value of commercial office space in the UK. This research considered a relatively small sample and was not based on transaction prices but on the assessors' valuations. The usage of assessed valuation of the properties (instead of transaction prices) can be an explanation for the non-consistent results. This idea is based on the findings of Warren-Myers (2013) which explain that valuers can represent a barrier for investment in sustainable properties, because of their lack of considering and reporting sustainability in the valuation process.

The underlying assumption is that developers apply for green building certification only when they expect a net benefit from the certificate. The following hypothesis is formulated:

Hypothesis 1. Buildings with green certification receive a price premium relative to buildings with no certification.

Another important area analyzed by the literature is the spatial distribution of green buildings. Due to the strong location dependence of returns in real estate investments, we expect that the net benefit of certification will also vary with the location of the project. Nelson (2007) documents that certified buildings are mostly concentrated in the CBD. Eichholtz et al. (2010) find that "the relative premium for green buildings is higher, ceteris paribus, in places where the economic premium for location is lower". Specifically, a green label appears to add more value in smaller markets and regions and in the more peripheral parts of larger metropolitan areas, where location prices and rents are lower. In other words, the increase in rent or value for a green building is systematically greater in smaller or lower-cost regions or in less expensive parts of metropolitan areas.

In central locations, even the highest level of green building certificate may not significantly add to the location advantage. Therefore, it may be that in the more peripheral locations the investment in a green building certificate can generate a higher net benefit. We expect the location by itself to be sufficient in high-rated districts for a project to receive a selling price premium. Considering this argument, we should be able to find spatial clusters of green buildings in cities. It is the aim of the proposed research to search for such spatial patterns of green buildings in European cities. Based on a more rigorous theoretical foundation, we intend to empirically analyze the spatial pattern of green office buildings in European cities.

By having access to data regarding the location of office buildings labelled green as well as the location of non-green buildings, we are able to assess if there is a significant spatial clustering of these categories of buildings. We use spatial point pattern analysis to identify significant clusters of green office buildings vs. non-green office buildings. This allows us to identify the impact of distance from the CBD on the location of the respective green buildings. The following hypothesis is therefore formulated.

Hypothesis 2. The price premium of buildings with green certification increases with the distance from the city center.

The next section presents the data sources and describes the sample selection process.

2. Methodology

2.1. Data

To address the research questions, a balanced panel data-set consisting of the DTZ Research Institute data enriched by hand-collection is used. Specifically, for testing the two hypotheses, a broad sample of green buildings in the European Union is harvested. The initial sample comprises of 61,827 building transactions in Europe in the retail, industrial, office or mixed-use sector, with transactions between 1997 and 2015. Moreover, the initial sample includes 299 green buildings with different types of green labels: BREEAM, DGNB, LEED, HQE. Data is gathered related to green office buildings by correlating the database with public information from BREEAM, LEED and DGNB databases. Moreover, the first filter was to analyze only office buildings in Europe, which resulted in a sample of 19,675 office buildings, out of which the sample included 229 green office buildings. Given that green building certification started developing in the EU after 2010, the previous years were excluded from the sample and considered only the 2010–2015 period.

Out of the resulting sample, 75.9 percent of green office buildings transactions were concentrated in the following countries: Finland, France and Germany. For a better data representation, the sample is limited to these three countries. In the end, the sample consists of 2576 transacted office buildings, out of which 174 are green office buildings. The certified buildings make for 6.8 percent of the overall sample. This proportion is consistent with Eichholtz et al. (2010), which have a 8.48 percent green sample for the rent premium test and 10.96 percent green sample for price premium test. Moreover, Fuerst and McAllister (2011a) reports that 6.25 percent of the overall sample consist of green buildings. All in all, the final sample is comparable with the ones of the previous US based studies on green certification.

Table 3 provides descriptive statistics. The characteristics of the sample are similar to those of comparable US samples used in extant literature.

Further, in Table 4 Pearson correlations of the main variables are presented. The relatively high positive correlation between Lat and Long results from the selection of countries.

Table 3
Descriptive statistics for the full sample and separated, for the green and non-green sub-samples.

	N	Minimum	Maximum	Mean	Std. Deviation
Size	2546	6800	37000	112695	1822405
Price	2546	60	41860.47	35271952	3272585
Dist	2546	−5.62	3.05	0.50	0.91
Pop	2546	9050	3460725	672470.78	933188
Year	2546	2010	2015	2012.26	1451
Valid N (listwise)	2546				
Non-Green buildings					
Size	2373	6800	37000	10806846	1829646
Price	2373	60	41860.47	34762804	32848
Dist	2373	−5.62	3.05	0.51	0.9159
Pop	2373	9050	3460725	685199.05	94075
Year	2373	2010	2015	2012.24	1467
Valid N (listwise)	2373				
Green buildings					
Size	174	17000	134000	176765	159144
Price	174	156.25	25393.60	42248	30134
Dist	174	−1.87	2.88	0.38	0.83
Pop	174	10716	3460725	495080.33	803145853
Year	174	2010	2015	2012.50	1191

Table 4
Pearson correlation matrix.

	Price	Size	Lat	Long	Pop	Dist
Price						
Size	−0.138					
Lat	−0.159	0.132				
Long	−0.447	0.212	0.548			
Pop	0.184	−0.003	0.254	0.260		
Dist	−0.195	0.083	0.241	0.009	−0.151	

2.2. Empirical models

2.2.1. Price premium

In real estate research, hedonic modelling is the preferred approach for analyzing the determinants of rent or price. This study follows previous literature (Eichholtz et al., 2010; Fuerst and McAllister, 2011a, b) and includes controls for various location and physical building characteristics in order to determine the impact of green certification on the selling price per square meter. The following OLS regression is consequently estimated:

$$\text{Price}_{ict} = \theta_0 + \theta_1\text{Green}_t + \theta_4\text{Country}_{ic,t-1} + \theta_5\text{Size}_{ict} + \theta_6\text{Pop}_{ict}a + \theta_7\text{Year}_{ict} + \theta_8\text{Lat}_{ict} + \theta_9\text{Long}_{ict} + \theta_{10}\text{Maincity}_{ict} + \varepsilon_{ict}, \quad (1)$$

$$\text{Price}_{ict} = \theta_0 + \theta_1\text{Green}_t + \theta_2\text{Dist}_i + \theta_3\text{Green}_t \cdot \text{Dist}_i + \theta_4\text{Country}_{ic,t-1} + \theta_5\text{Size}_{ict} + \theta_6\text{Pop}_{ict} + \theta_7\text{Year}_{ict} + \theta_8\text{Lat}_{ict} + \theta_9\text{Long}_{ict} + \theta_{10}\text{Maincity}_{ict} + \varepsilon_{ict}, \quad (2)$$

where, for building i, year t, and country c, similar to Eichholtz et al. (2010) and Fuerst and McAllister (2011a), it is defined Price_{ict} as the natural logarithm of price (in Euros) per square meter, Green_t is a dummy variable that takes the value 1 for buildings with green certification and the value 0 for buildings without green certification, and Dist_i is the natural logarithm of the geographical distance between the building and the city center. The distance (measured in meters) is determined by using the coordinates of latitude and longitude computed on the basis of the addresses provided in the DTZ database. Specifically, the distance variable is hand-constructed, based on the geocoding of the properties in the dataset. $\text{Country}_{ic,t-1}$ represents a country dummy. This variable controls for the inherent differences between the three countries in the sample. Size_{ict} is the natural logarithm of the property size (measured in square meters). This hedonic variable controls for the effect of large surfaces on the selling price. Pop_{ict} is the natural logarithm of population pertaining to the city where the building is located (measured in thousands of inhabitants), Year_{ict} is the year of transaction. Given that in the sample there are 5 years of data, this hedonic variable controls for the effect of confounding on the selling price. Lat_{ict} is the natural logarithm of the latitude coordinate of the building, Long_{ict} is the natural logarithm of the longitude coordinate of the building. The last two variables capture the effect of the spatial distribution of the buildings (Fuerst and McAllister, 2011a). Maincity_{ict} is a dummy variable that takes the value of 1 for larger cities in each country and 0 otherwise. ε_{ict} is a residual. Table 5 presents detailed definitions of the variables.

All independent continuous variables in the model have a logarithmic form in order to control for non-normality and heteroskedasticity. The logarithmic format also offers the possibility to interpret the coefficients of the estimation as percentages.

In the first model, the coefficient of Green_t captures the impact of green certification on the buildings' price. If positive (negative) and significant, the coefficient indicates that green buildings sell at a premium (discount) relative to comparable non-certificated buildings. According to the first hypothesis, it is expected that the green certification is associated to a price premium, so Green_t represents the first variable of interest. Size_{ict} and Year_{ict} are hedonic controls that isolate the effect of certification on price. Further, building on Fuerst and McAllister (2011a) Lat_{ict} and Long_{ict} are included in the model. These variables control for the spatial effect on the price of the buildings. Pop_{ict} and Dist_i are included in the model to mitigate the price impact of city size and distance from the center.

Table 5
Variable definition.

Variable name	Explanation
Price_{ict}	The natural logarithm of price per square meter
Green_{ict}	A dummy variable that takes the value 1 for buildings with green certification and the value 0 for buildings without green certification
Dist_{ict}	The natural logarithm of the geographical distance between the building and the city center. The distance is determined by using the coordinates of latitude and longitude computed on the basis of the addresses provided in the DTZ database
Size_{ict}	The natural logarithm of the property size measured in square meters
Lat_{ict}	The natural logarithm of the latitude coordinate of the building
Long_{ict}	The natural logarithm of the longitude coordinate of the building
Pop_{ict}	The natural logarithm of population pertaining to the city where the building is located
Maincity_{ict}	A dummy variable that takes the value 1 for top 5 cities in each country by number of inhabitants and the value 0 otherwise
Country_{ict}	The country dummy corresponding to Finland, France and Germany
Year_{ict}	The year dummy corresponding to the 2010–2015 period t

In the entire table, i stands for building, c for country and t for year.

Table 6
The price impact of green building certification and the incremental effect of distance from the city center.

	Price	Price	Price	Price	Price	Price
	(1)	(2)	(3)	(4)	(5)	(6)
Green	0.168***	0.172***	0.122**	0.117**	0.114**	0.129**
	(0.049)	(0.048)	(0.059)	(0.055)	(0.057)	(0.052)
Dist			−0.131***	−0.051***	−0.109***	−0.039**
			(0.017)	(0.016)	(0.018)	(0.016)
Green*Dist			0.118**	0.129**	0.111**	0.100**
			(0.055)	(0.051)	(0.053)	(0.050)
Pop		0.137***		0.130***		0.133***
		(0.008)		(0.008)		(0.008)
Maincity		0.360***		0.363***		0.363***
		(0.028)		(0.028)		(0.028)
Lat	3.335***	−0.216			2.927***	−0.290
	(0.415)	(0.430)			(0.421)	(0.433)
Long	−0.119**	−0.369***			−0.101**	−0.358***
	(0.046)	(0.048)			(0.046)	(0.048)
Size	0.000	−0.000	0.000	−0.000	0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	−5.645***	7.756***	7.737***	5.815***	−3.942**	8.094***
	(1.730)	(1.800)	(0.108)	(0.132)	(1.758)	(1.813)
Country	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2546	2512	2546	2512	2546	2512
R-squared	0.217	0.365	0.212	0.352	0.228	0.367

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.

In the second model, the variable of interest is the interaction between $Green_t$ and $Dist_i$. This interaction term measures the incremental effect of distance from the city center on the green certification premium. Specifically, if positive (negative) and significant, the variable indicates that the price premium of green certification increases (decreases) with distance from the city center. According to the second hypothesis, it is expected that the coefficient of $Green_t * Dist_i$ would be positive and significant. In the next section the results of the tests and explanations for the empirical findings are provided.

3. Results

3.1. Price premium

Reported results of the regression models in Tables 6–8. Columns 1 and 2 of Table 6 depict the results of the first regression of price on its normal determinants, as per Equation (1). Columns 3,4,5, and 6 present the results of the regression of price on its normal determinants, depending on distance, as per Equation (2). When estimating the model for the full sample, there are estimated six model specifications, in order to determine the sensitivity of the results to the inclusion/elimination of control variables. All models display similar results and explanatory power in any model specification. Consistent with previous literature, the coefficient of the *Green* dummy is positive and significant in all the model specifications. In Table 6, Column (2), where all control variables are included, the coefficient of *Green* is positive and significant at the 1 percent level, providing support for Hypothesis 1. The impact of the additional controls is underlined by the change in R-squared, from 21.7 percent to 36.5 percent. The latter value is similar to the one in Fuerst and McAllister (2011a). The value of the *Green* coefficient in Column (2) indicates a price premium of 19 percent for certified buildings relative to comparable non-certified buildings.[9] The positive sign and high explanatory power are maintained throughout the models. For the rest of the variables, the coefficients are consistent with the previous findings in the literature.

The second variable of interest is *Green*Dist*. Its coefficient is positive and significant in Table 6, Columns 3 to 6, corresponding to expectations. In Column 6, where all control variables are included, the coefficient of *Green*Dist* is positive and significant at the 1 percent level, providing support for Hypothesis 2. The value of the coefficient indicates an incremental price premium of 10.5 percent for the certified buildings that are located further away relative to other comparable certified buildings. Again, the impact of the additional controls included in the model is underlined by the change in R-squared, from 21.2 percent to 36.7 percent. These findings validate the second hypothesis. Further, the sample is split by city population. Specifically, tests are run using the dichotomy of main cities versus non-main cities. [10] The data in Table 7 suggest that the results remain unchanged in the no-Main cities, yet the coefficient of *Green*Dist* becomes insignificant for main cities. This finding suggests that the distance from the city center will not make a significant difference for the price premium of green buildings, since buildings in large cities are likely to have a price premium even as we move further from the city center.

Given the results of Table 7, the next step is to assess if the presence of the main city premium that cancels the incremental effect of distance will also hold for small cities. The sample is therefore split, to focus on cities of under 200,000 citizens. Table 8 shows results using the new, smaller sample. In all (four) model specifications, the coefficients of *Green* are positive and significant, consistent with the ones obtained using the full sample. In contrast, the coefficient of the *Green*Dist* interaction is insignificant, suggesting that the green certification in smaller cities does not depend on distance from the city center.

Overall, the results of our empirical analyses can be summarized as follows: in line with expectations, test results show that green

[9] This percentage is obtained by following the approach suggested by Halvorsen and Palmquist (1980). Specifically, since Green represents a dummy variable, it cannot be directly interpreted as a percentage premium. Instead, the premium is computed as exp(0.172)-1 = 19 percent.

[10] As before, the impact of the control variables is checked by observing a change in R-squared between the models, from 24.6 percent to 41.9 percent.

Table 7
The price impact of green certification and the incremental effect of distance from the city center in main and non-main cities.

	Price	Price	Price	Price	Price	Price	Price	Price	Price	Price
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Main	Main	Main	Main	Main	non-Main	non-Main	non-Main	non-Main	non-Main
Green	0.150**	0.158**	0.153**	0.185**	0.195***	0.162**	0.182***	0.181***	0.037	0.091
	(0.070)	(0.069)	(0.068)	(0.073)	(0.071)	(0.069)	(0.068)	(0.069)	(0.077)	(0.072)
Dist			−0.108***	−0.139***	−0.103***			−0.004	−0.117***	−0.022
			(0.021)	(0.022)	(0.022)			(0.023)	(0.025)	(0.024)
Green*Dist				−0.095	−0.103				0.269***	0.247***
				(0.074)	(0.076)				(0.065)	(0.063)
Size	−0.000***	−0.000**	−0.000**	−0.000***	−0.000**	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Population		0.075***	0.058***		0.058***		0.184***	0.183***		0.183***
		(0.011)	(0.012)		(0.012)		(0.011)	(0.011)		(0.011)
Lat	−1.162**	−2.343***	−2.609***	−1.894***	−2.632***	4.416***	1.774***	1.764***	4.070***	1.752***
	(0.573)	(0.596)	(0.597)	(0.578)	(0.598)	(0.542)	(0.591)	(0.592)	(0.547)	(0.595)
Long	−0.216**	−0.277***	−0.251***	−0.206**	−0.258***	−0.126**	−0.295***	−0.294***	−0.109**	−0.288***
	(0.092)	(0.093)	(0.088)	(0.088)	(0.089)	(0.050)	(0.062)	(0.062)	(0.049)	(0.062)
Constant	13.244***	17.040***	18.271***	16.105***	18.356***	−10.186***	−0.454	−0.410	−8.759***	−0.355
	(2.221)	(2.272)	(2.280)	(2.234)	(2.284)	(2.276)	(2.311)	(2.321)	(2.297)	(2.333)
Country	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1023	1023	1023	1023	1023	1523	1489	1489	1523	1489
R-squared	0.246	0.281	0.298	0.280	0.299	0.290	0.416	0.416	0.301	0.419

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.

Table 8
The price impact of green certification and the incremental effect of distance from the city center for cities with population <200,000.

	Price	Price	Price	Price
	(1)	(2)	(3)	(4)
	population<200,000	population<200,000	population<200,000	population<200,000
Green	0.269***	0.249***	0.236***	0.219***
	(0.055)	(0.053)	(0.060)	(0.057)
Dist			0.037	0.025
			(0.025)	(0.024)
Green*Dist			0.090	0.082
			(0.056)	(0.054)
Pop	−0.001	0.027	0.013	0.037
	(0.026)	(0.024)	(0.027)	(0.026)
Lat	1.971***	1.134**	2.085***	1.219**
	(0.598)	(0.560)	(0.609)	(0.574)
Long	−0.243***	−0.183***	−0.246***	−0.185***
	(0.059)	(0.054)	(0.058)	(0.054)
Maincity		0.450***		0.447***
		(0.039)		(0.039)
Size	0.000**	0.000	0.000**	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.178	3.143	−0.463	2.677
	(2.478)	(2.297)	(2.544)	(2.382)
Country	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	1377	1377	1377	1377
R-squared	0.280	0.340	0.282	0.342

Robust standard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.

certification brings a price premium of 19 percent relative to non-certified buildings. The magnitude of the premium is similar to what was documented in the studies of Fuerst and McAllister (2011c), Eichholtz et al. (2010), and Wiley et al. (2010). Further, results suggest that there is a significant incremental effect of distance on the price premium. Specifically, the green price premium is found to increase by 10.5 percent for a building located 1 km away from the city center. Nevertheless, when the analysis is restrained to buildings located in major cities or in cities of under 200,000 inhabitants, the distance effect becomes insignificant. This finding is in line with developers being able to benefit from the higher profitability of certification if they opt for non-central locations in medium-sized cities.

3.2. Sensitivity checks

To test the robustness of the findings and to further explore the impact of the green certification on the buildings' selling price, a number of additional tests are performed. First, to test the sensitivity of findings to the non-inclusion of the year 2010 in the sample. This is done in order to eliminate potential issues with respect to closeness to the 2008 financial crisis. Specifically, the aim is to test if the results are robust to eliminating the year closest to the high economic turmoil that might have had an impact on the buildings' selling prices. The sign and significance of the main coefficients of interest remain unchanged after the elimination of 2010. Also, tests are ran for assessing the impact of eliminating 2011

- the obtained results are weaker but qualitatively similar.[11] Second, o assure the robustness of the empirical inferences, a propensity score matching (PSM) approach developed by Rosenbaum and Rubin (1983) is employed. Specifically, the groups of green and non-green buildings are matched by size, to make sure they are more comparable. Subsequently, the main tests are re-run, and in spite of a weaker statistical significance, results remain qualitatively similar.

4. Conclusion

Given the fast expansion of green certification in Europe, central authorities are increasingly involved in supporting this trend. Concurrently, the interest to empirically determine the quantitative impact of certification is extremely relevant from the perspective of investors. This paper comes to answer this demand, by using proprietary data on three important countries in the EU - France, Finland, and Germany.

First, this study draws on the database provided by the DTZ Research Institute, enriched by hand-collected data, to document the existence of a price premium for office green certification. In quantitative terms, investors are willing to pay 19 percent more for an office building with green certifications relative to a comparable non-certified building. This finding suggests that there are clear benefits associated with green investment that are likely to outweigh the significant costs of green certification.

Second, based on geocoding of all properties in the database, it is investigated if the location of the building relative to the city center functions as a moderating contingency for the benefits associated with the certification premiums. A 10.5 percent incremental premium is documented - for certified buildings that are located farther from the city center. This finding is particularly important, as this is the first study to document that green office projects developed farther away from the CBD bring additional price premiums. Further tests suggest that for large cities or for cities of under 200,000 inhabitants, the location of the building becomes irrelevant. This result is explained by lower central location price premiums for both cases - the green certification will not be incrementally beneficial with distance from the city center.

Overall, this study contributes in multiple ways to the literature. To the authors' knowledge, this is the first empirical assessment of green certification for offices in several EU countries. Given the recent development of the green buildings market in the EU and the regulatory push for sustainable urban development (European Parliament, 2018), this study is both timely and relevant. Findings suggest that there are clear net benefits that emerge from investing in green office certification and the paper provides contextual information regarding the optimal placement of the development. By documenting that the location of the building is an important determinant of the benefit associated with the green certification, this study adds to the research stream focused on the economic viability of green investments. The results of empirical tests have important implications for the development of buildings with green certifications in the EU.

CRediT authorship contribution statement

Vlad-Andrei Porumb: Writing - review & editing, Conceptualization, Data curation, Writing - original draft, Methodology, Software, Formal analysis. **Gunther Maier:** Conceptualization, Software, Formal analysis, Data curation, Writing - original draft. **Ion Anghel:** Writing - original draft, Writing - review & editing, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Price is the natural logarithm of price per square meter, Size is the natural logarithm of property size in square meters, Lat is the natural logarithm of the latitude of the building, Long is the natural logarithm of the longitude of the building, Pop is the natural logarithm of the city's population and Dist is the natural logarithm of the geographical distance between the building and the city center.

Price is the natural logarithm of price per square meter, Size is the natural logarithm of property size in square meters, Lat is the natural logarithm of the latitude of the building, Long is the natural logarithm of the longitude of the building, Pop is the natural logarithm of the city's population and Dist is the natural logarithm of the geographical distance between the building and the city center.

The regression model is:

$$\begin{aligned}\text{Price}_{ict} = {} & \theta_0 + \theta_1\text{Green}_t + \theta_2\text{Dist}_i + \theta_3\text{Green}_t \cdot \text{Dist}_i \\ & +\theta_4\text{Country}_{ic,t-1} + \theta_5\text{Size}_{ict} + \theta_6\text{Pop}_{ict} + \theta_7\text{Year}_{ict} \\ & +\theta_8\text{Lat}_{ict} + \theta_9\text{Long}_{ict} + \theta_{10}\text{Maincity}_{ict} + \gamma_t + \delta_i + \varepsilon_{ict},\end{aligned} \tag{3}$$

where, for building i, year t, and country c, Price_{ict} is the natural logarithm of price per square meter, Green_t is a dummy for the green certification, Dist_i is the natural logarithm of the geographical distance between the building and the city center, $\text{Country}_{ic,t-1}$ is the country dummy, Size_{ict} is the natural logarithm of property size in square meters, Pop_{ict} is the natural logarithm of the city's population, Year_{ict} is the year dummy, Lat_{ict} is the natural logarithm of the latitude of the building, Long_{ict} is the natural logarithm of the longitude of the building, γ_t is a time effect, δ_i is a building fixed effect, and ε_{ict} is a residual.

The regression model is:

$$\begin{aligned}\text{Price}_{ict} = {} & \theta_0 + \theta_1\text{Green}_t + \theta_2\text{Dist}_i + \theta_3\text{Green}_t \cdot \text{Dist}_i \\ & +\theta_4\text{Country}_{ic,t-1} + \theta_5\text{Size}_{ict} + \theta_6\text{Pop}_{ict} + \theta_7\text{Year}_{ict} \\ & +\theta_8\text{Lat}_{ict} + \theta_9\text{Long}_{ict} + \gamma_t + \delta_i + \varepsilon_{ict},\end{aligned} \tag{4}$$

where, for building i, year t, and country c, Price_{ict} is the natural logarithm of price per square meter, Green_t is a dummy for the green certification, Dist_i is the natural logarithm of the geographical distance between the building and the city center, $\text{Country}_{ic,t-1}$ is the country dummy, Size_{ict} is the natural logarithm of property size in square meters, Pop_{ict} is the natural logarithm of the city's population, Year_{ict} is the year dummy, Lat_{ict} is the natural logarithm of the latitude of the building, Long_{ict} is the natural logarithm of the longitude of the building, γ_t is a time effect, δ_i is a building fixed effect, and ε_{ict} is a residual.

The regression model is:

$$\begin{aligned}\text{Price}_{ict} = {} & \theta_0 + \theta_1\text{Green}_t + \theta_2\text{Dist}_i + \theta_3\text{Green}_t \cdot \text{Dist}_i \\ & +\theta_4\text{Country}_{ic,t-1} + \theta_5\text{Size}_{ict} + \theta_6\text{Pop}_{ict} + \theta_7\text{Year}_{ict} \\ & +\theta_8\text{Lat}_{ict} + \theta_9\text{Long}_{ict} + \theta_{10}\text{Maincity}_{ict} + \gamma_t + \delta_i + \varepsilon_{ict},\end{aligned} \tag{5}$$

where, for building i, year t, and country c, Price_{ict} is the natural logarithm of price per square meter, Green_t is a dummy for the green certification, Dist_i is the natural logarithm of the geographical distance between the building and the city center, $\text{Country}_{ic,t-1}$ is the country dummy, Size_{ict} is the natural logarithm of property size in square meters, Pop_{ict} is the natural logarithm of the city's

[11] All results are available upon request.

population, $Year_{ict}$ is the year dummy, Lat_{ict} is the natural logarithm of the latitude of the building, $Long_{ict}$ is the natural logarithm of the longitude of the building, γ_t is a time effect, δ_i is a building fixed effect, and ε_{ict} is a residual.

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