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Green Building Adoption on Office Markets in Europe: An Empirical Investigation into LEED Certification

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Abstract: The goal of the paper is to evaluate the impact of selected factors on the adoption of LEED (Leadership in Energy and Environmental Design) green building certification in Europe. In the empirical part of the paper we track the fraction of LEED-registered office space in selected European cities, and assess the impact of selected socioeconomic and environmental factors on the certification adoption rate. This research contributes to the ongoing debate about the adoption of green buildings in commercial property markets. In this paper, we investigate factors affecting the adoption of LEED certification using the Arellano and Bond generalized method-of-moments estimator. Compared to prior studies, which relied on cross-sectional data, our research uses a panel approach to investigate the changes in green building adoption rates in selected European cities. Among the cities that are quickly adopting LEED are Frankfurt, Warsaw, Stockholm, and Dublin. The adoption process was not equally fast in Brussels and Copenhagen. Using the dynamic panel model approach, we found that the adoption of green building certification is linked to overall innovativeness in the economy and the perceived greenness of the city. Contrary to some previous studies we did not observe links between the size of the office market and the LEED adoption rate.

Keywords: sustainable buildings; certification system; LEED; diffusion of innovation; green building adoption

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Citation: Gluszak, M.; Malkowska, A.; Marona, B. Green Building Adoption on Office Markets in Europe: An Empirical Investigation into LEED Certification. *Energies* **2021**, *14*, 1971. https://doi.org/10.3390/en14071971

Academic Editors: Ernest Effah Ameyaw, Albert P. C. Chan and Amos Darko

Received: 25 February 2021
Accepted: 31 March 2021
Published: 2 April 2021

1. Introduction

Green buildings (also known as sustainable buildings, energy-efficient buildings, eco-buildings, or passive buildings) are the industry's answer to the requirement of sustainable development [1] which is one of the most important challenges of the contemporary economy [2]. The growing interest in green building issues is visible in several basic dimensions. First, attention should be paid to the development of the dedicated research in this field which is being undertaken by scientists from different parts of the world [3] representing various scientific disciplines, including economics, psychology, engineering, and management [4–7]. It is worth noting that these studies are conducted in the context of very different types of real estate, including residential [8] and commercial [9] as well as others [10]. Secondly, it is necessary to mention the creation and development of green building associations, supporting the creation and adaptation of multi-criteria assessment systems for the built environment in the context of compliance with the principles of sustainable development. In this context, an important role is played by green building rating systems, which are tools for evaluating buildings based on several objective criteria and clearly defined technical parameters. Among the most popular green certification systems are Leadership in Energy and Environmental Design (LEED) (launched in 1998) and Building Research Establishment Environmental Assessment Methodology (BREEAM) (launched in 1990), which are quite similar, analyze similar categories, and have a comparable cost. The differences between them are also primarily formal. However, it is worth mentioning that on the one hand, the number of certificates is growing and the numbers of buildings certified worldwide have exponentially increased from just a few at the end of the 20th century to many thousands today [11]. This second aspect, related to the worldwide spread of green buildings, was the starting point of our empirical study.

Our research was conducted in the area of commercial real estate which includes office properties. In this case, green buildings provide many benefits for various stakeholders (for example, investors, tenants, employees, and other users of buildings), not only direct financial but also economic, marketing, and social [9]. Despite much research in this area, in our opinion, there is a need for more detailed studies. A research gap exists especially in the field of empirical research and compared to prior studies, which relied on cross-sectional data, our research used a panel approach. In the paper we analyze the spatial diffusion of sustainable innovation across office markets in Europe and in doing so, we fit into the academic discussion regarding the extent, rate, and consequence of absorption of the sustainability paradigm in the real estate business and construction market [12]. The goal of the paper is to evaluate the impact of selected factors on the adoption of LEED certification in Europe. This research contributes to the ongoing debate about the adoption of green buildings in commercial property markets, based mainly on the U.S. [13–18].

The rest of the paper is organized as follows: The Background and Literature Review section offers a brief insight into the theoretical foundation of green building diffusion and provides an overview of research findings to date. The Material and Methods section discusses the indicator used to investigate the adoption of green technologies on office markets, as well as measures used to evaluate the adoption rate. The Results section discusses the dynamics of the LEED adoption rate and regression estimation results that allowed us to evaluate the role of selected factors affecting technology diffusion. We discuss the findings in light of the prior research and outline directions for future research in the last section, entitled Discussion and Conclusions.

2. Background and Literature Review

The framework for the study of diffusion and adaptation processes of the green building confirmed by eco-certificates lies in the well-established Diffusion of Innovation Theory, historically pioneered by Tard's early work (Les lois de l'imitation, 1890) [19,20], then intensively developed in the 1940s–1960s as a sociological study of the diffusion of agricultural innovations in the U.S. [21], and finally established and popularized by Roger's seminal work [22,23]. In Roger's view, "Diffusion of innovation is the process by which an innovation is communicated through certain channels over time among the members of a social system" [24] (p. 5). In this sense, diffusion is a social process based on communication in which knowledge about innovation and subjective evaluation of its benefits spreads through a community from earlier to later adopters. The diffusion of innovations takes place over time. Time is essential for the flow of the decision-making and the spread of knowledge as its basis [24] (p. 20). The time dimension is a delimiter of adapters' classes, distinguished by their innovativeness degree—innovators, early adopters, early majority, late majority, and laggards [25].

Along with the temporal dimension, geographical location and distance have also played a significant part in the diffusion of innovations. Diffusion is a spatio-temporal process whereby the characteristics of a place change as a result of previous events that occurred elsewhere. It, therefore, involves the spread of a particular phenomenon, in space and time, from limited origins [26] (p. 9). The groundwork for research on the spatial diffusion of innovation was laid by Swedish geographer Hägerstrand in his groundbreaking work [27], published in English in 1967 [28]. Hägerstrand saw diffusion as a geographic process resulting from interpersonal contact and information flow, influenced by time, the proximity of people (neighborhood effect), the ability to move innovation and information between areas, and the presence of physical and social barriers [29]. Hägerstrand's work sparked discussion of spatial diffusion and the development of research papers and analytical tools in this area, for instance [30–35].

Contemporary empirical research on the diffusion and adaptation of certified buildings across real estate markets, exploring the drivers of market penetration, draws not only on those general original theories but also on their subsequent extensions and adjustments to the type of innovations and industries. Koebel et al. [14] (p. 176) propose a general model for green building technology adaptation that includes seven multi-dimensional arrays drawn from diffusion and adaptation theory and previous research in this area. They address categories such as industry characteristics, market area characteristics, product characteristics, time, public policy, climate, and firm characteristics. Each contains a set of characteristics that can potentially be measured and incorporated into analytical models that examine green building diffusion and adaptation. In summarizing the research to date, Choi [36] highlights four general groups of factors that influence decisions in the sustainable building market. These are demand-side, supply-side, environmental condition, and public policy factors. Empirical research on the diffusion of certified office facilities overwhelmingly concerns the U.S. market and focuses on drivers of office market penetration and the spatial distribution of buildings at the level of major cities [36], core-based statistical areas (CBSA) [37], or metropolitan areas (MAs) [38].

Kok et al. [38] examined the spread of buildings certified for energy efficiency and sustainability (Energy Sar and LEED) across 48 U.S. metropolitan areas for 15 years (1995–2010). First, they find a relationship between the adoption of energy-efficient technology and building size, which is consistent with the general observation on technology diffusion that larger firms are more responsive to technological innovation. They also discovered that the diffusion curve for Energy Star-certificates matches the well-known S-shaped diffusion pattern of innovation. The purpose of Kok et al.'s study was to examine the impact of climatic, socioeconomic, real estate market, and policy variables on the dynamics of certified office space spread over time and space. They found that the adoption of green building innovations was faster in areas with higher pay and stronger income growth. This is consistent with previous studies, including, but not limited to, Cidell's research [39]. The second major factor affecting the diffusion of green buildings is the real estate market. Kok et al. identified that the size of the real estate market is important for diffusion processes—in markets with a higher supply of office space per employee, the adoption of certified buildings is quicker. In turn, higher vacancy rates negatively affect the growth of eco-labelled space. The third type of factor driving the growth of both—Energy Star and LEED-certified space has proven to be the price of commercial electricity.

Another influential paper examining the impact of climatic, socioeconomic, real estate market, and policy factors on the adoption of LEED-certified commercial buildings across 174 CBSA in the U.S. was that of Fuerst et al. [37]. They also found a significant positive impact of real estate market size on market penetration of LEED-certified buildings. Similar to the previously cited studies, areas with more affluent [38,39] and better-educated residents [39] have a higher proportion of LEED-certified buildings. When it comes to political drivers to stimulate green technology adoption, only mandatory requirements seem to matter. This conclusion follows the line of an earlier study by Choi [36] that focused on the impact of municipal policy tools on green building designation in central U.S. cities. Choi [36] also discovered that financial incentives do not affect green office building developments, however, he found a positive influence of regulatory policy and administrative incentives.

In addition to policy tools, a key factor for innovation diffusion processes is the social system. This follows from both Roger's innovation diffusion theory and the concept of spatial diffusion. As Broun et al. [40] point out, social attitudes toward environmental problems and green solutions are manifested in consumers' willingness to pay for green products, which influences actors' supply-side decisions and motivates the implementation of socially responsible practices. Besides, social trends also influence politicians and their tools for sustainable development and adaptation of green technologies. To address the societal influence on green building diffusion, Braun et al. [40] introduced the Green Sentiment Index, which reflects the public's environmental awareness in various areas of the U.S., into the analysis. They found a significant positive social impact on the adoption of LEED-certified properties in both public, commercial, and office buildings.

All of the cited works on the diffusion and adaptation of green office buildings are intra-urban analyses within the United States. Although green development is also of great importance to Europe and there is a growing body of research in this area, so far there are just a few cross-country studies investigating the diffusion of green technologies in housing markets [41,42]. Research on the penetration of green office buildings into European markets has so far been neglected. Therefore, we are convinced that our study, at least to some extent, narrows this gap by providing insights into the factors determining the varying degree of green building adoption in major European cities.

3. Materials and Methods

As a proxy for the adoption of green innovation on the office market in Europe we used the data on LEED-registered office projects. LEED is a multicriteria building assessment system established in 1998 by the United States Green Building Council (USGBC). It is widely considered as the global leader in green building assessment (Figure 1).

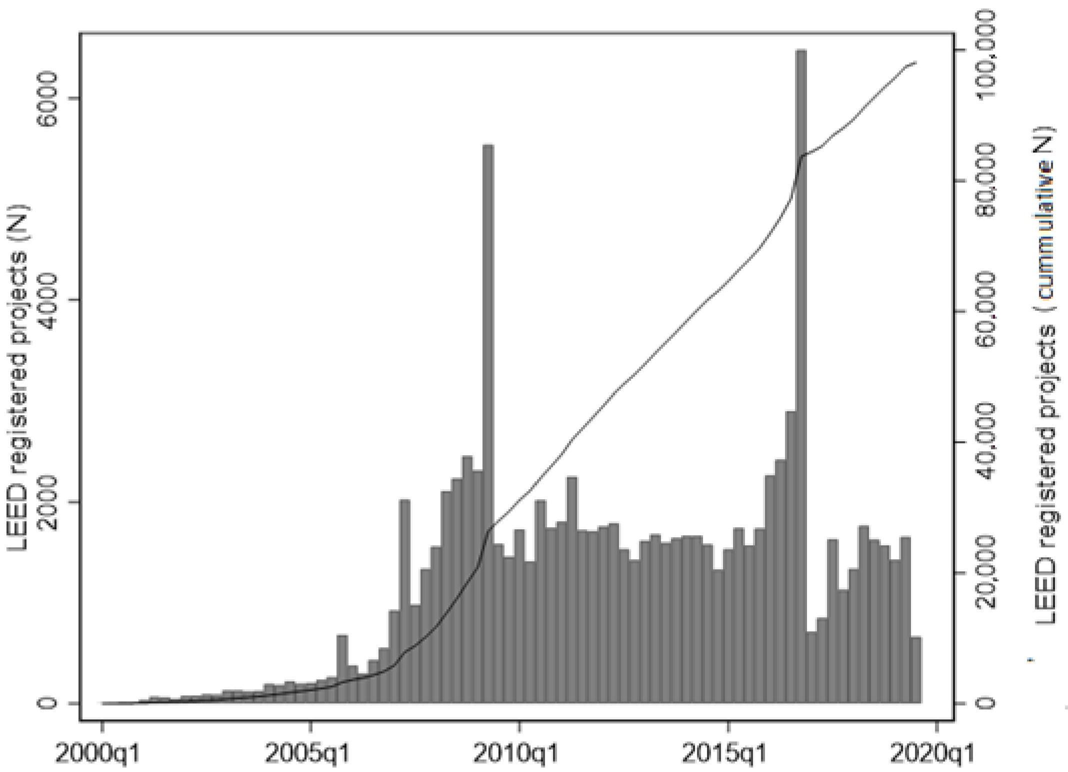

Figure 1. Global dynamics of project registration in LEED from 1q 2000 to 1q 2020 (quarterly).

Data reveals that it has a significant competitive position in Europe, where it ranks second amongst the various certification systems (Figures 2 and 3). The most popular green building labelling system in Europe is the Building Research Establishment Environmental Assessment Methodology (BREEAM) created in 1990 in the UK. Other important green building European certification systems are Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) created in 2007 by Deutsche Gesellschaft für Nachhaltiges Bauen e.V and Haute Qualité Environnementale (HQE) created in 1992 by Association pour la Haute Qualité Environnementale (ASSOHQE). Both of these has gained substantial popularity outside the domestic market—Germany and France, respectively.

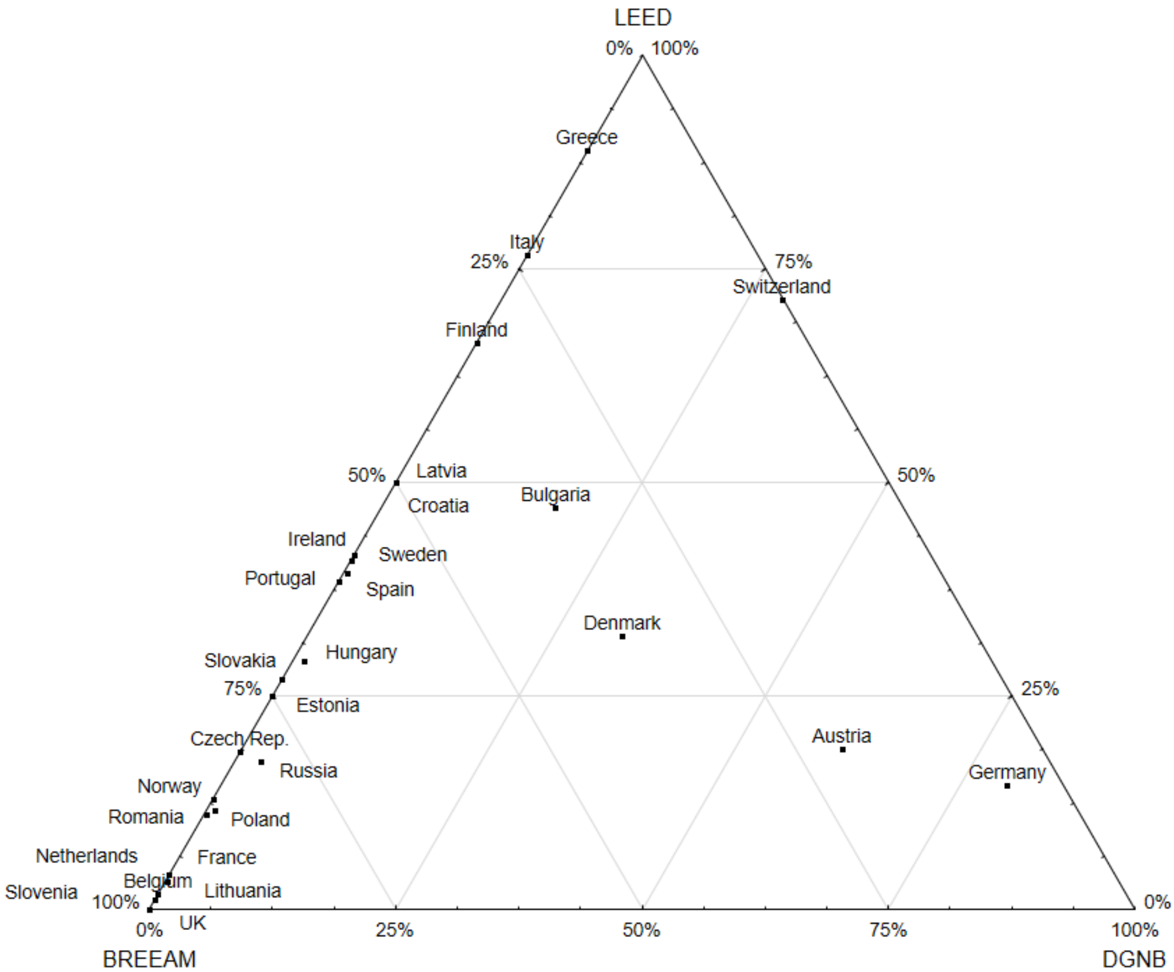

Figure 2. The competitive position of major green buildings certification systems in Europe in 2015.

In the paper, we analyzed the adoption of LEED green building certification for one basic reason. Unlike other major certification schemes present in Europe (i.e., BREEAM, HQE, and DGNB) LEED has been created not in one of the European countries but in the U.S. We believe that using LEED in the empirical part of the paper provides a good illustration of the adoption of green innovation on new commercial property markets outside the country of origin.

We investigated adoption in 14 cities in Europe (Amsterdam, Bruxelles, Copenhagen, Dublin, Frankfurt, Madrid, Milan, Munich, London, Manchester, Paris, Stockholm, Warsaw, and Zurich) over 11 year period (2008–2018).

We modelled green innovation diffusion, investigating the adoption rate across office markets in European cities using the fraction of LEED-registered office space as a dependent variable). We applied a simple measure of adoption of green technologies in the built environment, similar to Kok et al. [38]—the share of green buildings' area in the total building area in question. The dependent variable F_i (the fraction of LEED-registered office space in city i), is given by the following equation (Equation (1)):

$$F_i = \frac{z_i}{x_i}, \quad (1)$$

where z_i is the area of office space registered for LEED (in m^2), and x_i is a total office stock (m^2).

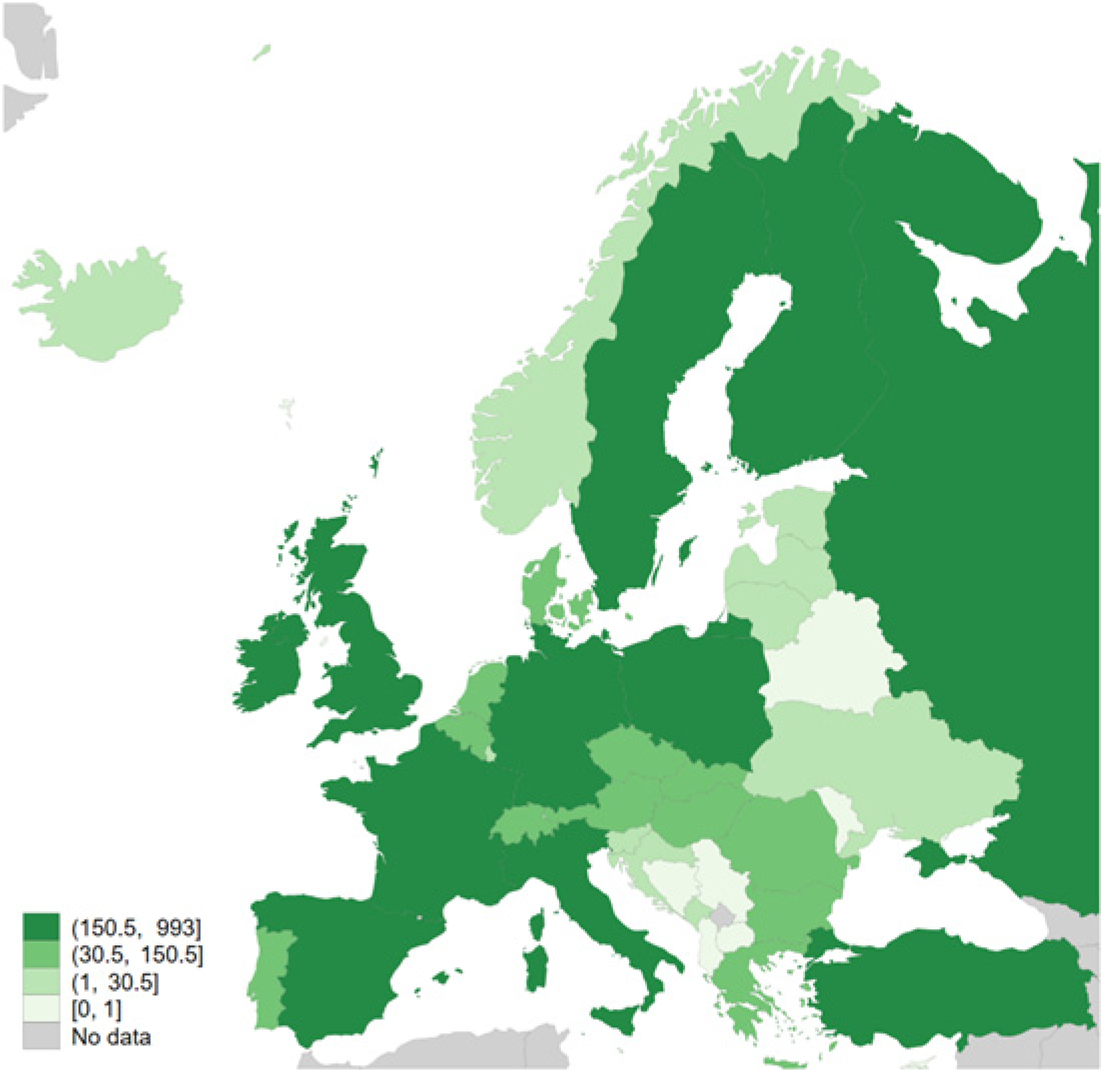

Figure 3. Spatial distribution of LEED-registered projects in Europe in 2018.

Aside from the fraction of LEED-registered (or certified) office space, other technology adoption measures have been applied in the literature [37,38]. Notably, Fuerst et al. [37] argue that a fraction indicator may lead to biased adoption estimates and opt for a variant of the spatial Gini coefficient. The formula is based on a proportion of LEED space in a given area normalized by the overall sustainable space. The G index [37] can be calculated according to the following formula (Equation (2)):

$$G = \sum_{i=1}^{N} \frac{z_i}{Z} - \frac{x_i}{X}, \quad (2)$$

where z_i, and x_i are as in Equation (1), Z is the sum of LEED-certified office space in all cities, and X is a total office stock in all cities.

Nonetheless, the G index indicator is not feasible in our research, as we focus on selected cities located in different countries.

In the research, we combined the data on LEED office buildings with the information on office stock to calculate the fraction of LEED-registered office space in a given year. We monitored the changes in the fraction of LEED space in 14 cities in Europe from 2008 to 2018 (11 years). To understand the green building diffusion process, using this balance panel setting we evaluated the influence of selected factors on the changes in the adoption rate (Figure 4).

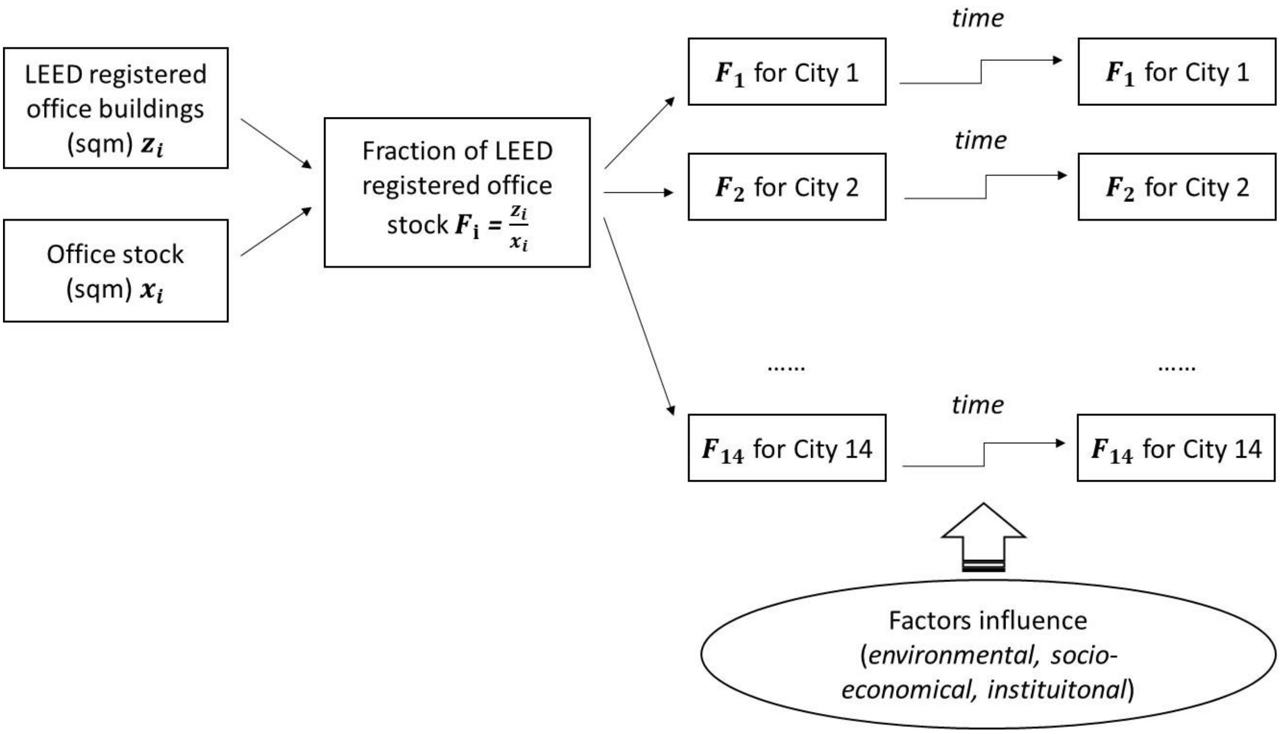

Figure 4. Analytical approach.

The data on LEED-registered projects came from the LEED Projects Directory administered by USGBC (https://www.usgbc.org/projects, accessed on 20 December 2020). The data on office stock (sto) and vacancy rate (vr) were collected from the Cushman & Wakefield market reports. Additionally, we used data on U.S. direct investment position abroad (usfdi) as a proxy of the relative activity of U.S. companies in the given country. We hypothesized that the strong presence of U.S. companies will foster the adoption of U.S.-originated green building certification. We also suspected that the adoption of green innovations may be faster in a more green and innovative environment. To account for that we used a fraction of citizens satisfied with green spaces (gre) and patent applications to the European Patent Office (pat) as proxy (Table 1).

Table 1. Explanatory variables.

Variable	Description	Source
sto	Office stock (thousands m^2)	Cushman & Wakefield
vr	Vacancy rate (fraction of available office space)	Cushman & Wakefield
usfdi	U.S. direct investment position abroad on an historical-cost basis (country level)	The U.S. Bureau of Economic Analysis.
gre	The fraction of citizens very satisfied with green spaces such as public parks or gardens in a given city	Eurostat
pat	Patent applications to the European Patent Office (EPO) (country level)	Eurostat

The analysis of the adoption of green building technologies on major office markets in Europe is presented in the following section.

4. Results

Simple exploratory analysis (see Figures 2 and 3) indicates that the LEED certification scheme has not been equally successful in European countries. We observed that there are significant differences in the usage of LEED green building labels between European countries—some of them influenced by the presence of domestic green building certification systems (BREEAM in the UK, DGNB in Germany, and HQE in France). Further analysis revealed divergent pathways of LEED adoption in selected European cities (see Figure 5). Among the cities quickly adopting LEED are Frankfurt, Warsaw, Stockholm, and Dublin, where the fraction of LEED-registered space increased significantly during the study period (2008–2018) The adoption was not as fast and smooth in Milan, Munich, Madrid, or Amsterdam, where the fraction of LEED space rose steadily, but less dynamically. Finally, the LEED adoption process was considerably slower in Brussels or Copenhagen (Figure 5).

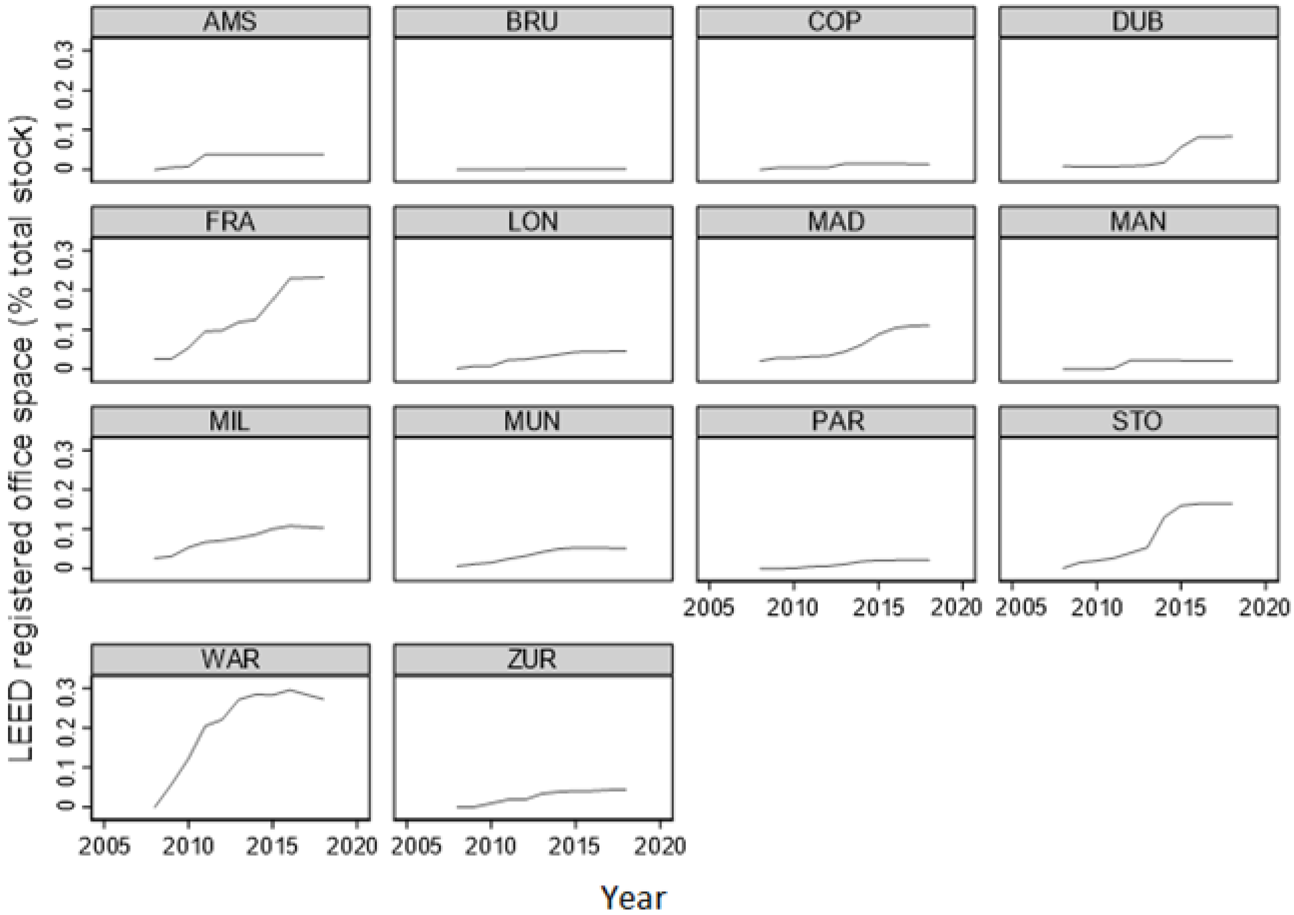

Figure 5. Adoption of LEED in selected European office markets (2008–2018).

The differences between the European cities in the adoption of LEED certification (or green building adoption in general for that matter) may be related to various factors. The diffusion of green technologies and the adoption of green building certifications may be driven by environmental policies or regulations, climate and weather conditions, or salient socioeconomic conditions that vary between locations and change over time.

Using a standard dynamic panel setting (14 office markets observed over 11 years) we investigated the impact of factors on the LEED building adoption rate. We evaluated how selected economic and environmental indicators affect the adoption of LEED certification using the Arellano and Bond [43] generalized method-of-moments (GMM) estimator. The results of the estimation are presented in Table 2. The dependent variable is the fraction of LEED-registered office space.

Table 2. Estimation results (Arellano–Bond GMM).

Adoption	Coefficient	Standard Error	*p*-Value	Sig
Adoption (t−1)	0.770365	0.0502722	0.000	***
sto	-1.18×10^{-6}	3.56×10^{-6}	0.741	
vr	−0.0139054	0.0107669	0.197	
usfdi	1.28×10^{-8}	3.49×10^{-8}	0.713	
gre	0.0015072	0.0005952	0.011	*
pat	0.0005556	0.0001428	0.000	***
Cons	−0.1218724	0.0444197	0.006	**
Groups		14		
Observations		126		
Wald Chi2		735.58		

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The dynamic panel model used in the research allows us to account for dynamic adjustments in the adoption of green technologies within selected office markets, by adding the lagged dependent variable as a regressor in an econometric model. The coefficient for the lagged dependent variable is positive (0.77) and statistically significant. We observed a positive (0.0015) and significant impact of the fraction of citizens satisfied with green spaces in a given city and LEED adoption rate (measured as a fraction of LEED-registered office stock). This particular result suggests that the adoption of green building certification is positively linked with environmental controls in the study. One surprising result is that U.S. Direct Investment abroad (usfdi) did not influence the fraction of LEED-registered space. We hypothesized that significant U.S. investment, along with the presence of U.S. companies, could facilitate the diffusion of LEED certification, which is a domestic and default green building certificate in the United States. It was not the case.

Contrary to prior research based on U.S. data we did not observe a positive impact of the size of the office market (measured as office stock) on the adoption of LEED certification. A positive coefficient would suggest that adoption is faster and stronger in major office markets (first-tier). It was not the case in our sample. The coefficient is not statistically significant. We did not observe a significant relationship between the vacancy rate and adoption rate.

We also observed a positive impact of the number of patent applications to the European Patent Office (EPO) in a given country on the fraction of LEED-registered office space in a city (0.0005556). This may provide limited support for the notion that the overall innovativeness of the economy translates into the adoption of green innovation in the real estate industry.

5. Discussion and Conclusions

Using empirical data on the LEED certification scheme in the European office market context we found that citizens' level of satisfaction with green spaces (i.e., public parks or gardens), used as a proxy for overall city greenness, was positively linked with the green building adoption indicator. The estimates suggest that the LEED adoption rate in selected European cities was also positively linked with the overall level of innovation in the economy (patent applications to the EPO). We did not observe the impact of the U.S. Direct Investment on the adoption of LEED certification schemes. Nonetheless, the links between the presence of U.S. companies in given cities and office market willingness to adopt U.S. green building certification schemes needs to be explored in future—preferably using city-level variables.

The set of explanatory variables differed significantly from prior U.S.-based studies by Fuerst et al. [37] and Kok [38]. The before-mentioned studies explored the role of climate zone, ideology/political variables, and environmental policy incentives. Some of these variables either did not seem well-suited into the European context (republican vs. democratic) or were not feasible from a data-gathering perspective (obtaining comparable data from various European countries is far more complicated than in the U.S.). Compared to those studies, we explored the role of innovativeness and the role of the U.S. FDI in a given country on the adoption of USGBC LEED certification. None of these issues had been investigated before. Contrary to some of the prior studies, which relied on cross-sectional data [37], our research used a panel approach to investigate the changes in green building adoption rates in selected European cities. There are several limitations and natural extensions of this research. One obvious limitation stems from the fact that we used the fraction of LEED-registered space as a proxy for green building diffusion. That particular approach results in two fundamental problems. Firstly, as discussed in Kok et al.'s [38] seminal paper, one of the weaknesses of the approach lies in the fact that certification is a voluntary procedure (some green buildings are not certified, based on the owners' decision). Secondly, the European context is far more challenging than the American, due to fierce competition from domestic certification systems (BREEAM in the UK, DGNB in Germany and Austria, and HQE in France). In that respect, the adoption of LEED certification is hampered by strong competition. As a consequence, the fraction of LEED-certified buildings will not represent the true level of green building diffusion in a given office market. On the other hand, this particular finding has some implications for those interested in the promotion of LEED green building certification in Europe. Adoption of LEED certification seemed to be significantly faster in countries without domestic competitors. Therefore, focusing on those markets could result in strengthening the competitive position of LEED certification compared to its European counterparts.

The results of the empirical investigation described in this paper suggest several directions for further research. A natural extension of the study, albeit challenging from the data collection perspective, would be combining major certification schemes (LEED, DGNB, BREEAM, and HQE) when calculating the overall green space in given cities. Additionally, in the paper, we focused on major office markets in selected countries in Europe. The follow-up study should extend the sample size, and include smaller regional markets, preferably using hierarchical country-level controls to account for differences in the institutional framework. The latter analytical approach would allow some econometric problems of our research to be mitigated. The results are based on a relatively small sample (only 14 compared to 48 in Kok et al.'s U.S. study [37] making the Arellano–Bond [43] estimator problematic (it performs best in panels with small T and large N). This problem will be mitigated provided data on smaller regional office markets are used in future studies. Moreover, using green office building data for smaller European cities would allow exploration of how green technologies are adopted in second-tier and third-tier office markets.

Author Contributions: Conceptualization, M.G., A.M., and B.M.; methodology, M.G. and A.M.; software, M.G.; validation, M.G., A.M., and B.M.; formal analysis, M.G., A.M., and B.M.; investigation, M.G., A.M., and B.M.; resources, M.G., A.M., and B.M.; data curation, M.G.; writing—original draft preparation, M.G., A.M., and B.M.; writing—review and editing, M.G., A.M., and B.M.; visualization, M.G.; supervision, M.G.; project administration, B.M.; funding acquisition, M.G. and A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This project has been financed by the Ministry of Science and Higher Education within the "Regional Initiative of Excellence" Programme for 2019–2022. Grant number 021/RID/2018/19.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: https://www.usgbc.org/projects (accessed on 1 April 2021); https://ec.europa.eu/eurostat/home (accessed on 1 April 2021); https://www.bea.gov/international/di1usdbal; https://www.cushmanwakefield.com/en (accessed on 1 April 2021).

Conflicts of Interest: The authors declare no conflict of interest.

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