Capitalization of energy efficiency on corporate real estate portfolio value

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Abstract

Purpose – The purpose of this paper is to investigate whether energy efficiency is capitalized in rent and asset value on corporate real estate portfolio. This approach contributes to the research on "green buildings" by using hedonic regression modeling on a portfolio of existing buildings in the French corporate real estate context.

Design/methodology/approach – The authors apply hedonic methods on a French corporate real estate portfolio which is composed of industrial, commercial and office buildings.

Findings – This model emphasizes two main results: energy efficiency is more capitalized in rent than in asset value and this relationship differs regarding buildings' type.

Originality/value – The model suggests that premium for energy efficiency is stronger for commercial and office buildings than for industrial buildings.

Keywords Corporate real estate, Rental value, Industrial property, Commercial property, Green buildings, Energy efficiency, France

Paper type Research paper

Introduction

This article investigates the impact of energy efficiency on the economic value of existing buildings in a large corporate real estate portfolio. Sustainability is becoming a major issue for real estate sector, as building and associate activities are approximately responsible for 30 percent of greenhouse gas emissions (RICS, 2005). The improvement of sustainability in real estate is largely supported by a reinforced regulation such as the *Grenelle de l'Environnement* in France and the emergence of rating systems which certifies buildings for sustainability such as the Environmental Protection Agency's Energy-Star or the label of the US Green Building Council "LEED", the *BREEAM* label in the UK or the high environmental quality (*HQE*) and high energy performance (*HPE*) labels in France. However, the diffusion of sustainable principles also allowed the actors to consider the potential value created by sustainable buildings in a context of corporate social responsibility (Pivo and Fisher, 2010). Following this, a body of research studying "green buildings" has emerged.

The potential value of green buildings is generally attributed to attractiveness for occupiers due to energy efficiency, productivity, employees' well-being, potential gains on tax and other incentives, "socially responsible" image (Ellison *et al.*, 2007; Kats, 2009); and decreased risk for investors (Sayce *et al.*, 2004; Lorenz and Lützkendorf, 2008;

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McNamara, 2008). A growing number of empirical works use hedonic regression modeling to demonstrate that these advantages can turn into rental premium, higher occupancy rates and thus higher asset values (Miller *et al.*, 2008; Eichholtz *et al.*, 2010; Wiley *et al.*, 2010; Fuerst and McAllister, 2011).

The aim of this article is to contribute to the growing literature on "green buildings". Most of the contributions in this literature deal with buildings that are certified for sustainable performance and concern mainly USA, UK and Australia which represent 75 percent of academic publications (Sayce *et al.*, 2010). Following this, it should be interesting to study the potential valuation of sustainable practices in a different context. An important contribution of this paper is to conduct an approach focused on a portfolio of existing non-certified buildings in the French context where studies on green buildings valuation remain scarce. This approach is supported by a research convention which allows us to have access to a large corporate real estate portfolio including data on energy efficiency. The data come from the portfolio of *Poste Immo*: the landholding trust which optimises, develops, manages and maintains real estate assets of the French Post Office operator (*La Poste*). We thus investigate the potential valuation of green performance (energy consumption) into rent and asset value on a portfolio of existing buildings using hedonic regression modeling. This approach allows us to overcome the lack of data available in the French context concerning office buildings certified *HQE* or *HPE* for sustainable performance. The results of the model emphasize a positive impact of energy efficiency which is capitalized into rent and asset value. This effect seems stronger for rent than for asset value and differs regarding buildings' type.

The article is structured as follows: first section describes the theoretical and empirical background on green buildings; second section presents the method by describing the dataset and the specification of the hedonic model; the results are discussed in the third section; finally, the fourth section concludes.

Background

In the context of corporate real estate, sustainable principles emerged with the reinforcement of regulation constraint (such as the *Grenelle de l'Environnement* in France) and highlighted the potential value of environmental performance for buildings, defined in the literature by the notion of "green value". Sustainable performances are supported by several rating systems and are expected to increase buildings' value. In France, buildings are certified for energy efficiency regarding the *HPE* label and certified for sustainability regarding the *HQE* label which relies on 14 targets concerning the impact of the building on its external environment and its ability to create a qualitative internal environment.

This section emphasizes the main factors of attractiveness for sustainable buildings, and the growing number of empirical studies estimating the impact of green attributes on office buildings valuation.

Environmental performance and attractiveness for office buildings

Several studies argue that sustainability may improve buildings' attractiveness for occupiers and decrease risk for investors. The main advantages for occupiers are well documented in the recent literature on green buildings. They rely on savings on operating expenses due to energy efficiency and other utilities, productivity gains and improvement of employees' well-being, potential gains on tax and other incentives by adapting to a changing regulation, and competitive advantages linked to marketing and "socially responsible" image (Ellison *et al.*, 2007; Kats, 2009). A potential occupier will thus consider these advantages which should lead to higher occupation rate and rental premium for sustainable buildings. The key question consists in evaluating the occupier's "willingness to pay" for these advantages (Fuerst and McAllister, 2011). Several studies investigate these advantages for users based on surveys conducted across actual green buildings' occupiers (Heerwagen, 2000; Edwards, 2006; Paul and Taylor, 2008; Brown *et al.*, 2010). The surveys conducted across occupiers by Jones Lang LaSalle (2008) and Cushman & Wakefield (2009) in London, or DTZ (2009) in Paris confirm the improvement of sustainability among other strategic factors for buildings' attractiveness and a willingness to pay a premium for green-certified buildings from 1-5 to 10 percent. A recent study based on a survey conducted across a large sample of corporate real estate managers shows that sustainability impacts location choice of users in the French context (Nappi-Choulet and Décamps, 2011).

Empirical research on green office buildings valuation

Sustainable performances should improve buildings' attractiveness for occupiers leading to higher occupancy rates and premium on rents or asset values. A theoretical framework of the price premium of green buildings can be found in Fuerst and McAllister (2011). However, the main research contributions on economic value of green buildings are empirical studies using hedonic models.

Hedonic regression modeling is the standard methodology for examining price and rent determinants in real estate research. Hedonic analysis is derived from the theoretical framework of Lancaster (1966) and Rosen (1974) which consider that any heterogeneous good (such as buildings) consists of a variety of utility-bearing characteristics. The hedonic price function is thus a combination of implicit prices estimated for each characteristic. This "revealed preference" method is often used in the empirical literature of real estate valuation regressing buildings' prices on a set of intrinsic characteristics and location attributes.

However, the application of hedonic models is scarcer for office buildings than for housing. This is primarily explained by the difficulty of collecting the necessary data concerning properties' characteristics, generally less reliable for offices than for housing (Downs and Slade, 1999), especially in the French case (Nappi-Choulet *et al.*, 2007; Nappi-Choulet and Maury, 2009). The main determinants explaining the formation of rents are well established in this literature and rely on building size, age, number of stories, vacancy level, type of lease and location attributes. Whereas the main determinants of the sales price usually concerns building size, age, number of stories and location attributes.

Hedonic regression methods have been recently adapted to test the effect of green buildings on rents and asset values (Miller *et al.*, 2008; Eichholtz *et al.*, 2010; Wiley *et al.*, 2010; Fuerst and McAllister, 2011). These studies use Energy-Star or LEED certification as proxies for green design. Certified buildings from the CoStar database are compared with a set of "regular" office buildings in order to estimate the impact of certification. They all conclude to a positive impact of sustainable certification. Depending on the studies, the rent premium is estimated between 2 and 9 percent for Energy-Star certified buildings and between 4 and 18 percent for LEED certified buildings. The studies investigating the impact of certification on sales prices estimate a premium between 13 and 26 percent for Energy-Star buildings and between 11 and 25 percent for

LEED buildings. While this literature is widely developed in USA, UK and Australia (Sayce *et al.*, 2010), it is scarcer in the French context due to a lack of available data, especially for *HQE* or *HPE* certified buildings. In this article, we overcome this limitation by accessing to a real estate investor's portfolio including data on energy efficiency (the full dataset is described in the following section).

Moreover, the literature on green buildings usually focuses on the advantages of certified buildings compared to "regular" buildings. It should be interesting to study the potential conversion to sustainable practices for existing non-certified buildings, "since no more than 2 percent of the existing stock is built in any one year" (Miller *et al.*, 2010). This paper estimates the potential valuation impact of energy efficiency on rent and asset value in a portfolio of existing non-certified buildings in the French context (the dataset is described in details in the following section).

Method

Hedonic regression modeling is used to test the impact of energy consumption on the economic value of buildings in a corporate real estate portfolio. This section describes the database coming from this portfolio and the specification of the hedonic model.

Data source: a large corporate real estate portfolio

The data collected for this article come from the portfolio of *Poste Immo*: the landholding trust which optimises, develops, manages and maintains real estate assets of the French Post Office operator (*La Poste*). *Poste Immo* is a major real estate operator in the French context with a portfolio composed by 13,300 buildings, 7 million square metres, 4 million of which are fully owned. A research convention with this major operator allowed us to have access to a sample of its portfolio for which audits have been conducted to measure energy efficiency and sustainable performance. This sample is composed by the 558 buildings considered by *Poste Immo* as the most important ones, classified as "Strategic" or "Significative", representing more than 2 million square metres. The selection of the sample has been guided by accessibility to data providing information on economic value as well as intrinsic and location characteristics and sustainable performances.

The data base of this article represents a sample of 558 buildings characterized by the following variables (2010):

- Asset value (based on appraisal) and rent.
- A set of buildings' intrinsic characteristics which are usually used in hedonic literature, as mentioned in the previous section: buildings' size (in square metres), age, number of stories, and type of lease (differentiated if the occupier is *La Poste* or an external company).
- Building type: *Industrial* (warehouses and their office spaces), *Tertiary* or *Mixed – Post Office* (buildings characterized by a post office activity and at least another use).
- The own *Poste Immo*'s classification for buildings, which can be: Strategic or Significative.
- The location code of the French National Institute of Statistics and Economic Studies for each building which allows us to specify two types of local variables: the employment level of each building's location and a set of dummy variable controlling for each local market. These two local variables are coded at two

different scales to avoid potential colinearity problems: "communes" for employment level and "departements" for dummy variables.

- The energy consumption (in kilo watt per hour per square meter per year) for each building. This variable is the main interest variable of our model as it represents energy efficiency. A classification in nine items (from A to I) is produced by the French official *Energy Performance Diagnosis* method regarding performance in energy consumption.

The descriptive statistics of this dataset is detailed in Tables AI and AII (Appendix 1). A limitation of this dataset is the relatively low number of buildings in our sample regarding the contributions using the CoStar database. However, using data from a corporate real estate portfolio, this article provides two main contributions. First, it allows us to overcome the lack of data available in the French context to analyze the economic valuation of green buildings (to our knowledge, this is the only hedonic model which tests the impact of sustainable performance on buildings' economic value in the French context). Second, it contributes to the academic research on green buildings by investigating the potential value of energy efficiency for existing non-certified buildings.

Specification of a hedonic model

In order to explain rent and asset value of buildings in our sample, we specify the usual log-linear hedonic model which is adapted to test the impact of energy efficiency:

$$\ln P_i = \alpha + \beta_i X_i + \gamma_i C_i + \delta_i LM_i + \varepsilon_i \tag{1}$$

In this formulation, $ln\ P_i$ is the natural logarithm of rent or asset value for building i; X_i is a vector of locational and intrinsic characteristics of building i (with every quantitative variables transformed in natural logarithm in order to be interpreted as elasticities); C_i represents the energy consumption of building i (dummy variables for each consumption class in kilowatt per hour per square meter per year); LM_i is a set of dummy variables controlling for each local market[1] (corresponding to the administrative zoning in "departements" of the French National Institute of Statistics and Economic Studies); and ε_i a random error term which is assumed to be normally distributed (this property is confirmed by the test of *Jarque-Bera*).

This log-linear formulation of the hedonic model is widely used in the main contributions concerning green buildings cited in the previous section, as it captures non-linearity. However, a Box-Cox transformation (Box and Cox, 1964) has been estimated here in order to justify this specification choice. This method allows an endogenous estimation of the functional form of the model by estimating a parameter λ for the explained variable. The Box-Cox transformation is based on the following form:

$$P_i^{(\lambda)} = \begin{cases} \ln(P), & \lambda = 0 \\ \frac{P^{\lambda}-1}{\lambda}, & \lambda \neq 0 \end{cases}$$

The functional form of the model thus depends on the value of the estimated parameter, especially between 0 corresponding to the log-linear specification and 1 corresponding to the standard linear specification. The λ parameter is estimated using the maximization of log-likelihood. The results of this estimation are presented in Table AIII (Appendix 2) and systematically confirm the log-linear specification for the model.

Following this, two models are specified: Model 1 explains asset value and Model 2 explains rent.

Model 1:

$$\ln V_i = \alpha + \beta_{1i} T_i + \beta_{2i} S_i + \beta_{3i} ln\, BS_i + \beta_{4i} NS_i + \beta_{5i} A_i + \beta_{6i} ln\, E_i + \gamma_i C_i + \delta_i LM_i + \varepsilon_i \quad (2)$$

In this model, V_i represents the asset value of building i; T_i is buildings' type (dummy variables for each type: *Industry*, *Tertiary* or *Mixed – Post Office*); S_i is a dummy variable which is equal to 1 if the building is a Strategic one and 0 if not; BS_i represents the building size (in square meter); NS_i is the number of stories (coded in dummy variables); A_i the age of building i (coded in dummy variables); E_i represents the employment level of building i's location and LM_i is the set of dummy variables controlling for each local market. Employment level is measured at a different scale (administrative zoning in "communes" of the French National Institute of Statistics and Economic Studies) than local market dummies to avoid potential colinearity problems. Finally, C_i represents the energy consumption of building i (in kilowatt per hour, per square meter, per year). The energy consumption is specified in two different ways (Model 1a and 1b). First, we use dummy variables for each class of consumption of the French official *Energy Performance Diagnosis*. However, our sample's buildings are highly concentrated in the central classes D, E and F (Table AII in Appendix 1). We thus introduce the deciles of energy consumption in order to have a more equitable distribution of buildings in the different classes of consumption. The consumption thresholds corresponding to each decile are given in Table I for the different subsamples.

Model 2:

$$\ln R_i = \alpha + \beta_{1i} T_i + \beta_{2i} S_i + \beta_{3i} ln\, BS_i + \beta_{4i} NS_i + \beta_{5i} A_i + \beta_{6i} ln\, E_i + \beta_{7i} LT_i + \gamma_i C_i + \delta_i LM_i + \varepsilon_i \quad (3)$$

In this model, R_i represents rent in building i. All the explanatory variables are the same as in Model 1, as well as the two specifications for energy consumption (Model 2a with consumption class and Model 2b with consumption deciles). We add a variable LT_i concerning the type of lease contracts which is differentiated if there is an external occupier in the building.

Equations of Models 1 and 2 are both estimated using the standard OLS technique, where the potential heteroskedasticity[2] of residuals has been taken into account with

	Overall sample	*Industrial*	*Tertiary*	*Mixed – Post Office*
D1	172	188	147	172
D2	208	213	173	212
D3	226	231	210	223
D4	253	259	244	245
D5	276	283	261	266
D6	295	299	276	284
D7	327	340	327	312
D8	367	381	368	343
D9	436	460	496	387
D10	>436	>460	>496	>387

Table I.
Deciles of energy consumption (kilowatt per hour per square meter per year)

a robust covariance matrix estimated using White's (1980) method. Potential colinearity between variables is tested using variation inflation factor statistics (*VIF*). The hedonic weights assigned to each variable are equivalent to the characteristic's overall contribution to the variability of rent or asset value (Rosen, 1974).

Results

The results of the models confirm the capitalization of energy efficiency in asset value and rent. This relationship appears to be more important for rent than for asset value and differs regarding buildings' type. Models 1 and 2 are first estimated to test the impact of energy consumption on asset value and rent on the overall sample. Then, each model is specified separately on three types of buildings: *Industry*, *Tertiary* and *Mixed – Post Office*.

The impact of energy consumption on asset value and rent

The results of Models 1 and 2 on the overall sample are detailed in Tables AIV and AV (Appendix 3) concerning intrinsic characteristics, location attributes and energy consumption. They suggest that energy consumption impacts asset value and rent. However, this result seems stronger for rent than for asset value.

In Model 1 (Table AIV), the coefficients of intrinsic characteristics are usually statistically significant and vary with the expected sign. The elasticity between asset value and building size is estimated at a level of 0.77. There is a positive relationship between asset value and number of stories. Age impacts negatively asset value. Concerning buildings' type, *Tertiary* and *Mixed – Post Office* have a positive impact on asset value whereas the coefficient of *Industrial* buildings is not statistically significant. Concerning local variable, as expected, the employment level has a positive and significant impact on asset value, and the control variables representing Paris Metropolitan Area have the strongest positive and significant effect.

Energy efficiency is specified in two ways: Model 1a with dummy variables for each class of *Energy Performance Diagnosis* and Model 1b with dummy variables for each decile. Coefficients are systematically estimated regarding low performance (i.e. high energy consumption): dummy variables for class G, H and I or decile 10 are omitted. The impact of energy consumption on asset value is generally non-significant. However, a positive and significant impact is associated with decile 8 (regarding decile 10) of energy consumption which concerns buildings consuming less than 367 kilowatt per hour per square meter per year. This effect can be interpreted as a premium estimated at 20 percent for leaving the less performing group and reaching the central group which concentrates the majority of buildings.

In Model 2 (Table AV), the intrinsic characteristics are still statistically significant with the expected sign, even if the number of stories is less significant than in Model 1. The elasticity between rent and building size is estimated at a level of 0.81 and age impacts negatively rent. The positive impact of lease type is stronger for an external occupier than if the occupier is *La Poste*. Buildings' type has not a significant impact on rent. As in Model 1, local variable have a significant impact on rent with the expected sign: a positive impact of local employment level and a strong impact of Paris Metropolitan Area.

If energy consumption has not a strong significant effect on rent, this effect seems to be more important than in Model 1. A positive and significant impact is estimated at

20 percent for decile 8 (less than 367 kilowatt per hour per square meter per year) and another estimated at 18 percent for decile 4 (less than 253 kilowatt per hour per square meter per year). We thus identify two thresholds for which energy efficiency impacts rent. The first one can be interpreted as a premium for leaving the less performing group and reaching the central group which concentrates the majority of buildings, as in Model 1. The second can be interpreted as a premium for reaching the more performing buildings (regarding central group).

Even if the impact of energy consumption on rent and asset value is generally not significant, the results of Models 1 and 2 suggest that energy efficiency can be capitalized at different thresholds. However, this relationship seems stronger for rent than for asset value. This analysis has to be sharpened by differentiating between types of buildings in our sample.

The relationship differs regarding buildings' type

There are three types of buildings in our sample: *Industrial*, *Tertiary* and *Mixed – Post Office*. We estimate Models 1 and 2 to test the impact of energy efficiency on asset value and rent on each of these subsamples (descriptive statistics of each subsample can be found in Tables AI and AII in Appendix 1).

As mentioned earlier, a limitation of our sample is a relatively low number of buildings. This limitation is increased by creating subsamples for each building's type. We thus modify the models in order to decrease the number of variables regarding the size of the subsamples: the set of dummy variables controlling for each local market is replaced by a unique dummy variable $Paris_i$ coded 1 if building i is located in Paris Metropolitan Area (the strongest effect among local market controls) and 0 if not. In addition, the employment level of each building location is differentiated regarding buildings' type: employment level in industrial sector for *Industrial* buildings and employment level in tertiary sector for *Tertiary* and *Mixed – Post Office* buildings.

As indicated by the models estimated on the overall sample, the results suggest that energy efficiency affects more rent than asset value. The impact of energy efficiency on asset value (Model 1) is generally not significant (the results are thus not reported here), except for *Industrial* buildings for which we only observe a negative impact on asset value (and rent) for the less energy performing buildings. However, the impact of energy efficiency on rent (Model 2) seems to be more significant depending on buildings' type. We focus on the results of *Tertiary* and *Mixed – Post Office* buildings for which the results are very significant (we only observe a negative effect of being in the less energy performing group for the *Industrial* buildings).

The results of Model 2 for *Tertiary* and *Mixed – Post Office* buildings are presented in Tables AVI and AVII (Appendix 3).

Concerning intrinsic characteristics, the elasticity between rent and building size is estimated at a level of 0.96 for *Tertiary* buildings and 0.66 for *Mixed – Post Office* buildings. This gap can be interpreted by the fact that *Mixed – Post Office* buildings are usually characterized by high building size. The variations of building size thus impact less rent variations than for *Tertiary* buildings. The number of stories has a positive impact on rent for *Tertiary* buildings whereas only a low number of stories has a positive impact on rent for *Mixed – Post Office* buildings. Age has not a significant impact on rent for both subsamples. Finally, lease type has a positive impact on rent only if the occupier is *La Poste* for both subsamples. Concerning local variables, employment level has a positive and significant effect on rent for both subsamples and the *Paris* variable has a positive and significant impact on rent for *Mixed – Post Office* buildings but surprisingly not for *Tertiary* buildings.

Energy consumption has a strong significant impact on rent for these two buildings' types. For *Mixed – Post Office* buildings the coefficients associated with consumption classes of *Energy Performance Diagnosis* emphasize a positive impact of classes F and E (less than 450 and 330 kilowatt per hour per square meter per year) which can be interpreted as a premium for leaving the less performing group which strongly increase for reaching the best performance in energy consumption (class B: less than 90 kilowatt per hour per square meter per year). This result is even stronger for *Tertiary* buildings with a premium increasing all along classes and deciles measuring energy efficiency, from the effect of leaving the less performing group (decile 8 or class E) to the best performing buildings (decile 1 or class B). Even if the value of the coefficient must be interpreted with caution due to the size of the subsamples, this result strongly indicates a positive relationship between energy efficiency and rent.

The hedonic model of this article indicates a positive effect of energy efficiency on economic value of existing non-certified buildings in a corporate real estate portfolio. Two main results are emphasized. First, this relationship seems to be more important for rent than for asset value. This result can be interpreted by considering that asset value is determined by a market expertise (appraisal) whereas rent involves directly the occupier. It suggests that potential gains linked to energy efficiency are attractive for users even if it involves extra rental cost. Second, the effect of energy efficiency differs regarding buildings' type: if the impact is relatively low for *Industrial* buildings probably because of the specific characteristics of these buildings, it seems to play an important role on the determination of rent for *Tertiary* and *Mixed – Post Office* buildings.

The impact of energy efficiency on economic value estimated by the different specifications of the model on the different subsamples is summarized in Table II.

These results contribute to the academic literature on green buildings' valuation. They also provide innovative results for practitioners and society as they highlight the potential economic valuation that real estate owners can expect by improving sustainable performance of their buildings. Although well-known factors such as buildings' characteristics and location attributes explain most of the value of a building, this paper demonstrates that energy efficiency can be an additional leverage to create value. The results also suggest that this extra-value may come from the occupiers' willingness to pay for sustainable performance. This should help real estate landlords to make strategic choices between selling or adding value, refreshing buildings and/or renegotiate leases.

Conclusion

The aim of this article is to contribute to the growing literature on green buildings by testing the impact of energy efficiency on the economic value of existing non-certified buildings in the French context. This approach uses hedonic regression modeling to demonstrate that energy efficiency has a positive impact on asset value and rent. The model is supported by a dataset coming from a real estate portfolio for which audits have been conducted on sustainable performance of buildings.

Table II.
Impact of energy efficiency on economic value

	Asset value	Rent
Overall sample	Premium for leaving the less performing group	Premium for leaving the less performing group and reaching the more performing buildings
Industrial	Negative impact of less performing buildings only	Negative impact of less performing buildings only
Mixed – Post Office	Not significant	Premium for leaving the less performing group and reaching the more performing buildings
Tertiary	Not significant	Positive relationship between energy efficiency and rent all along energy consumption thresholds

The hedonic model estimates the contribution of energy consumption (kilowatt per hour per square meter per year) on rent and asset value regarding the contribution of a set of buildings' intrinsic characteristics and location attributes. The model is specified on the overall sample and then for each building's type in our sample: *Industrial*, *Tertiary* and *Mixed – Post Office*. Two main results are emphasized by the model. First, energy efficiency is more capitalized in rent which involves directly the occupier's willingness to pay than in asset value coming from appraisal. The value premium seems to be first driven by rental income which may impact market expertise in a second step. This contributes to the body of works confirming that sustainable performances are valued by occupiers (see Nappi-Choulet and Décamps (2011) in the French context). The second main result of this article shows that premium linked to energy efficiency differs regarding buildings' type which should guide strategic choices among a real estate portfolio. In our sample, the effect of energy efficiency on rent is relatively low for *Industrial* buildings, whereas it is much stronger for commercial and office buildings.

The research perspectives of this article are conditioned to the access of a larger database in order to increase the number of buildings in our sample and to test the relationship between energy efficiency, asset value and rent on other types of buildings. This article is supported by a database concerning one real estate investor. It allowed us to overcome the lack of data on the French context, but a limitation of the model is a relatively small sample. A larger sample with an access to data from several investors' portfolio might overcome this limitation and improve our findings.

Notes

1. We also tested a more precise local variable to control for micro-location (*within a city* or *outside a city*). As it did not improve the model's statistical robustness when added to the standard local dummy variables, we did not keep it.
2. In the presence of heteroskedasticity, the ordinary least squares (OLS) estimator can be biased because of heterogeneous error terms associated with the different explanatory variables. A robust covariance matrix must be used in this case.

References

Box, G.E.P. and Cox, D.R. (1964), "An analysis of transformations", *Journal of the Royal Statistical Society, Series B*, Vol. 26 No. 2, pp. 211-252.

Brown, Z., Cole, R.J., Robinson, J. and Dowlatabadi, H. (2010), "Evaluating user experience in green buildings in relation to workplace culture and context", *Facilities*, Vol. 28 Nos 3/4, pp. 225-238.

Cushman & Wakefield (2009), *European Landlord and Tenant Survey 2009*, Cushman & Wakefield, London.

Downs, D. and Slade, B. (1999), "Characteristics of a full-disclosure, transaction-based index of commercial real estate", *Journal of Real Estate Portfolio Management*, Vol. 5 No. 1, pp. 95-104.

DTZ (2009), *Green Real Estate*, DTZ, Paris.

Edwards, B. (2006), "Benefits of green offices in the UK: analysis from examples built in the 1990s", *Sustainable Development*, Vol. 14 No. 3, pp. 190-204.

Eichholtz, P., Kok, N. and Quigley, J. (2010), "Doing well by doing good? Green office buildings", *American Economic Review*, Vol. 100 No. 5, pp. 2494-2511.

Ellison, L., Sayce, S. and Smith, J. (2007), "Socially responsible property investment: qualifying the relationship between sustainability and investment property worth", *Journal of Property Research*, Vol. 24 No. 3, pp. 191-219.

Fuerst, F. and McAllister, P. (2011), "Green noise or green value? Measuring the effects of environmental certification on office values", *Real Estate Economics*, Vol. 39 No. 1, pp. 45-69.

Heerwagen, J.H. (2000), "Green buildings, organizational success, and occupant productivity", *Building Research & Information*, Vol. 28 No. 5, pp. 353-367.

Jones Lang LaSalle (2008), *Global Trends in Sustainable Real Estate: An Occupiers Perspective*, Jones Lang LaSalle, London.

Kats, G. (2009), *Greening Our Built World: Costs, Benefits, and Strategies*, Island Press, Washington, DC.

Lancaster, K. (1966), "A new approach to consumer theory", *Journal of Political Economy*, Vol. 74, pp. 132-157.

Lorenz, D. and Lützkendorf, T. (2008), "Sustainability in property valuation: theory and practice", *Journal of Property, Investment and Finance*, Vol. 26 No. 6, pp. 482-521.

McNamara, P. (2008), *Will Greener Buildings Bring Bigger Profits?*, Professional Investor, pp. 41-43, available at: www.cfauk.org

Miller, N., Spivey, J. and Florance, A. (2008), "Does green pay off?", *Journal of Real Estate Portfolio Management*, Vol. 14 No. 4, pp. 385-401.

Miller, N., Pogue, D., Saville, J. and Tu, C. (2010), "The operations and management of green buildings in the United States", *Journal of Sustainable Real Estate*, Vol. 2 No. 1, pp. 51-66.

Nappi-Choulet, I. and Décamps, A. (2011), "Is sustainability attractive for corporate real estate decisions?", No. WP1106, ESSEC Research Center.

Nappi-Choulet, I. and Maury, T.P. (2009), "A spatiotemporal autoregressive price index for the Paris office property market", *Real Estate Economics*, Vol. 37 No. 2, pp. 305-340.

Nappi-Choulet, I., Maleyre, I. and Maury, T.P. (2007), "A hedonic model of office prices in Paris and its immediate suburbs", *Journal of Property Research*, Vol. 24 No. 3, pp. 241-263.

Paul, W.L. and Taylor, P.A. (2008), "A comparison of occupant comfort and satisfaction between a green building and a conventional building", *Building and Environment*, Vol. 43, pp. 1858-1870.

Pivo, G. and Fisher, J.D. (2010), "Income, value, and returns in socially responsible office properties", *Journal of Real Estate Research*, Vol. 32 No. 3, pp. 243-270.

RICS (2005), *Green Value: Green Buildings, Growing Assets*, Royal Institution of Chartered Surveyors, London.

Rosen, S. (1974), "Hedonic prices and implicit markets: product differentiation in pure competition", *Journal of Political Economy*, Vol. 82, pp. 34-55.

Sayce, S., Ellison, L. and Smith, J. (2004), "Incorporating sustainability in commercial property appraisal: evidence from the UK", paper presented at 11th European Real estate Society Conference, Milan, Italy, 2-4 June.

Sayce, S., Sunberg, A. and Clements, B. (2010), *Is Sustainability Reflected in Commercial Property Prices: An Analysis of the Evidence Base*, RICS Research, Royal Institution of Chartered Surveyors, London, 99 pp.

White, H. (1980), "A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity", *Econometrica*, Vol. 48 No. 1, pp. 817-838.

Wiley, J.A., Benefield, J.B. and Johnson, K.H. (2010), "Green design and the market for commercial office space", *Journal of Real Estate Finance and Economics*, Vol. 41 No. 2, pp. 228-243.

Further reading

Atisreal (2008), *True' Sustainability and the UK Property Market*, Atisreal, London.

Bubny, P. (2009), "UGC: green cost premium disappears", October 6, available at: www.globest.com/news/1510_1510/newyork/181437-1.html

Mills, E. (1992), "Office rent determinants in the Chicago area", *AREUEA Journal*, Vol. 20, pp. 156-171.

Appendix 1

Quantitative variables	Mean	Median	SD
Overall sample			
Building size	3,441.48	1,889.13	4,685.82
Age	35.04	29.00	31.17
Number of stories	2.47	2.00	1.39
Lease type			
External	0.14	0.00	0.45
La Poste	2.53	2.00	3.59
Employment level	136,344.55	17,669.40	405,388.49
Energy consumption	295.89	276.50	130.69
Industrial			
Building size	3,613.60	1,774.97	4,877.34
Age	16.98	6.00	24.85
Number of stories	1.92	2.00	0.87
Lease type			
External	0.02	0.00	0.13
La Poste	1.46	1.00	1.11
Employment level	4,909.57	1,202.13	14,363.30
Energy consumption	306.37	283.00	127.89
Mixed – Post Office			
Building size	2,035.37	1,616.92	1,383.07
Age	46.71	38.00	26.11
Number of stories	2.43	2.00	1.05
Lease type			
External	0.13	0.00	0.33
La Poste	2.56	2.00	1.40
Employment level	51,299.97	8,225.35	191,423.66
Energy consumption	275.34	266.00	101.00
Tertiary			
Building size	6,986.14	4,673.85	7,144.98
Age	53.44	50.00	29.12
Number of stories	4.38	4.00	1.76
Lease type			
External	0.55	0.00	0.89
La Poste	5.96	4.00	7.81
Employment level	103,998.54	30,347.88	274,487.52
Energy consumption	296.94	261.50	181.10

Table AI. Descriptive statistics on quantitative variables

Qualitatives variables	Observation	% of the sample
Industrial	247	44.27
Mixed – Post Office	190	34.05
Tertiary	86	15.41
Strategic	74	13.26
Paris	112	20
Energy consumption		
Class_A	1	0.18
Class_B	11	1.97
Class_C	24	4.30
Class_D	143	25.63
Class_E	217	38.89
Class_F	113	20.25
Class_G	29	5.20
Class_H	14	2.51
Class_I	6	1.08
Total	558	100

Table AII.
Descriptive statistics on quantitative variables

Appendix 2

	Model 1a		Model 1b		Model 2a		Model 2b	
	R^2	Log-likelihood	R^2	Log-likelihood	R^2	Log-likelihood	R^2	Log-likelihood
Overall sample								
$\lambda = 0$	0.81	−7,580.0	0.81	−7,582.1	0.81	−6,223.2	0.81	−6,224.0
$\lambda = 1$	0.47	−8,683.0	0.46	−8,682.8	0.58	−7,111.0	0.58	−7,111.1
Mixed – Post Office								
$\lambda = 0$					0.75	−2,400.21	0.75	−2,397.44
$\lambda = 1$					0.64	−2,581.94	0.64	−2,580.44
Tertiary								
$\lambda = 0$					0.93	−990.13	0.91	−996.60
$\lambda = 1$					0.75	−1,115.59	0.73	−1,115.55

Table AIII.
Box-Cox transformation

Appendix 3

Asset value	Model 1a Coefficient	Model 1a p-value	Model 1b Coefficient	Model 1b p-value
Building Type (T_i)				
Industrial	0.039	0.678	0.035	0.714
Tertiary	*0.295* *	*0.006*	*0.285* *	*0.008*
Mixed – Post Office	*0.354* ***	*0.000*	*0.357* ***	*0.0001*
Strategic (S_i)	0.017	0.783	0.026	0.681
Ln Building Size (BS_i)	*0.765* ***	*< 0.0001*	*0.766* ***	*< 0.0001*
Ln Employment (E_i)	*0.067* ***	*0.000*	*0.064* ***	*0.000*
Number of Stories (NS_i)				
NbStories_1	−0.124	0.151	−0.117	0.177
NbStories_2	*−0.220* **	*0.003*	*−0.219* **	*0.004*
NbStories_3	*−0.353* ***	*< 0.0001*	*−0.355* ***	*< 0.0001*
Age (A_i)				
AGE_D1	*0.296* **	*0.004*	*0.292* **	*0.004*
AGE_D2	*0.318* ***	*0.000*	*0.316* ***	*0.000*
AGE_D3	0.110	0.198	0.109	0.203
AGE_D4	*−0.213* **	*0.009*	*−0.218* *	*0.008*
AGE_D5	*−0.144* *	*0.077*	*−0.140* *	*0.087*
AGE_D6	*−0.145* *	*0.089*	*−0.146* *	*0.089*
AGE_D7	−0.106	0.223	−0.115	0.187
AGE_D8	*−0.158* *	*0.061*	*−0.157* *	*0.062*
AGE_D9	−0.069	0.414	−0.066	0.438
Energy Consumption (C_i)				
D1 (172)	−0.094	0.303		
D2 (208)	−0.083	0.328		
D3 (226)	−0.015	0.857		
D4 (253)	0.040	0.636		
D5 (276)	−0.078	0.354		
D6 (295)	0.037	0.656		
D7 (327)	−0.006	0.944		
D8 (367)	*0.197* **	*0.015*		
D9 (436)	0.048	0.560		
classB (90)			−0.114	0.508
classC (150)			−0.126	0.281
classD (230)			−0.057	0.451
classE (330)			−0.004	0.951
classF (450)			0.107	0.150
Local Control Variables (LM_i)	Included		Included	
Adjusted R^2	0.77		0.77	
Observations	559		559	

Note: Significant at: *10, **5 and ***1 percent levels

Table AIV. Results of Model 1 on the overall sample

Rent	Model 2a Coefficient	Model 2a p-value	Model 2b Coefficient	Model 2b p-value
Building Type (T_i)				
Industrial	−0.075	0.458	−0.071	0.482
Tertiary	0.145	0.213	0.148	0.203
Mixed – Post Office	0.049	0.607	0.063	0.515
Strategic (S_i)	−0.022	0.745	−0.014	0.837
Ln Building Size (BS_i)	*0.812******	*< 0.0001*	*0.815******	*< 0.0001*
Ln Employment (E_i)	*0.060***	*0.002*	*0.059***	*0.002*
Lease Type (LT_i)				
External	*0.126***	*0.017*	*0.117***	*0.027*
La Poste	*0.011**	*0.078*	*0.010**	*0.095*
Number of Stories (NS_i)				
NbStories_1	0.100	0.277	0.104	0.263
NbStories_2	−0.075	0.346	−0.075	0.348
NbStories_3	*−0.205***	*0.010*	*−0.215**	*0.007*
Age (A_i)				
AG E_D1	*0.336***	*0.002*	*0.323***	*0.003*
AG E_D2	*0.327****	*0.000*	*0.323****	*0.000*
AGE_D3	0.064	0.480	0.065	0.471
AG E_D4	*−0.175***	*0.044*	*−0.189***	*0.030*
AGE_D5	−0.022	0.802	−0.023	0.791
AGE_D6	*−0.160**	*0.079*	*−0.160**	*0.081*
AGE_D7	−0.010	0.918	−0.025	0.790
AGE_D8	−0.110	0.223	−0.115	0.201
AGE_D9	−0.062	0.499	−0.060	0.512
Energy Consumption (C_i)				
D1 (172)	−0.039	0.693		
D2 (208)	0.045	0.620		
D3 (226)	0.115	0.208		
D4 (253)	*0.182***	*0.047*		
D5 (276)	0.095	0.287		
D6 (295)	0.089	0.320		
D7 (327)	0.113	0.197		
D8 (367)	*0.206***	*0.018*		
D9 (436)	0.044	0.623		
classB (90)			0.018	0.923
classC (150)			−0.078	0.528
classD (230)			0.064	0.436
classE (330)			0.110	0.149
classF (450)			0.112	0.166
Local Control Variables (LM_i)	Included		Included	
Adjusted R^2	0.77		0.77	
Observations	550		550	

Note: Significant at: *10, **5 and ***1 percent levels

Table AV. Results of Model 2 on the overall sample

Rent	Model 2a Coefficient	Model 2a p-value	Model 2b Coefficient	Model 2b p-value
Paris$_i$	*0.474* ***	< *0.0001*	*0.489* ***	< *0.0001*
Strategic (S_i)	−0.128	0.190	−0.133	0.172
Ln Building Size (BS_i)	*0.654* ***	< *0.0001*	*0.658* ***	< *0.0001*
Ln Employment (E_i)	*0.137* ***	< *0.0001*	*0.138* ***	< *0.0001*
Lease Type (LT_i)				
External	−0.003	0.973	0.025	0.752
La Poste	*0.079* ***	*0.001*	*0.067* **	*0.006*
Number of Stories (NS_i)				
NbStories_1	*0.346* ***	*0.000*	*0.299* ***	*0.001*
NbStories_2	0.032	0.609	0.043	0.483
Age (Ai)				
AGE_D1	0.184	0.121	*0.191* *	*0.092*
AGE_D2	−0.047	0.683	−0.060	0.596
AGE_D3	−0.039	0.732	0.039	0.723
AGE_D4	−0.075	0.558	−0.030	0.809
AGE_D5	0.141	0.200	*0.181* *	*0.096*
AGE_D6	0.003	0.981	0.074	0.504
AGE_D7	−0.040	0.725	0.025	0.823
AGE_D8	0.009	0.935	0.029	0.791
AGE_D9	−0.053	0.644	0.023	0.841
Energy Consumption (C_i)				
D1 (172)	0.060	0.632		
D2 (212)	−0.002	0.986		
D3 (223)	−0.016	0.901		
D4 (245)	0.150	0.225		
D5 (266)	−0.038	0.752		
D6 (284)	−0.078	0.526		
D7 (312)	0.110	0.336		
D8 (343)	−0.045	0.698		
D9 (387)	0.182	0.119		
classB (90)			*0.606* *	*0.006*
classC (150)			0.065	0.700
classD (230)			0.217	0.109
classE (330)			*0.217* *	*0.085*
classF (450)			*0.291* **	*0.023*
Adjusted R^2	0.72		0.72	
Observations	221		221	

Note: Significant at: *10, **5 and ***1 percent levels

Table AVI.
Results of Model 2 for *Mixed – Post Office* buildings

Rent	Model 2a Coefficient	Model 2a p-value	Model 2b Coefficient	Model 2b p-value
$Paris_i$	0.231	0.174	0.198	0.258
Strategic (S_i)	−0.167	0.221	−0.198	0.170
Ln Building Size (BS_i)	*0.946******	*< 0.0001*	*0.976******	*< 0.0001*
Ln Employment (E_i)	*0.216******	*< 0.0001*	*0.206******	*< 0.0001*
Lease Type (LT_i)				
External	−0.110	0.164	−0.123	0.113
La Poste	*0.010**	*0.099*	0.008	0.212
Number of Stories (NS_i)				
NbStories_1	*−0.322**	*0.061*	*−0.332****	*0.049*
NbStories_2	*−0.344****	*0.032*	*−0.368****	*0.021*
NbStories _3	−0.042	0.806	−0.017	0.920
Age (A_i)				
AGE_D1	0.013	0.952	−0.027	0.900
AGE_D2	0.121	0.550	0.037	0.861
AGE_D3	0.080	0.678	0.043	0.828
AGE_D4	−0.051	0.795	−0.037	0.857
AGE_D5	0.052	0.814	−0.046	0.845
AGE_D6	0.045	0.821	0.055	0.795
AGE_D7	0.262	0.253	0.277	0.262
AGE_D8	0.089	0.679	0.045	0.838
AGE_D9	−0.010	0.964	−0.135	0.547
Energy Consumption (C_i)				
D1_conso (147)	*0.770******	*0.001*		
D2_conso (173)	0.173	0.487		
D3_conso (210)	*0.552****	*0.027*		
D4_conso (244)	*0.583****	*0.017*		
D5_conso (261)	*0.535****	*0.024*		
D6_conso (276)	*0.670****	*0.006*		
D7_conso (327)	*0.445**	*0.097*		
D8_conso (368)	*0.475**	*0.055*		
D9_conso (496)	0.335	0.153		
classB (90)			*0.568**	*0.064*
classC (150)			*0.492****	*0.047*
classD (230)			0.331	0.125
classE (330)			*0.462****	*0.029*
classF (450)			0.278	0.195
Adjusted R^2	0.89		0.88	
Observations	83		83	

Note: Significant at: *10, **5 and ***1 percent levels

Table AVII.
Results of Model 2 for *Tertiary* buildings

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