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Income risk in energy efficient office buildings

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ABSTRACT

This article examines the impact of improving energy efficiency of office buildings on their financial risk. While multiple studies report a sustainability premium little is known about the corresponding risk. This research reviews the financial benefits in the context of their impact on risk. After a theoretical analysis of the topic, it forms two hypotheses which are supported with empirical tests performed on a large panel dataset of US commercial office buildings. Changes in the magnitude of the green premium in rent and changes in rental volatility are used as indicators of financial risk associated with energy certification. The study concludes that acquiring an EnergyStar certificate is related to a structural change in statistical characteristics of rents which may be related to the level of energy efficiency. The average effect is positive but varies over time.

1. Introduction

The body of literature that claims that focusing on sustainability can positively influence financial returns continues to grow (Eichholtz, Kok, & Quigley, 2013; Epstein, Buhovac, & Yuthas, 2015; Matisoff, Noonan, & Flowers, 2016) and, despite fact that the concept is very general and its meaning elusive, gain popularity in the world of finance (Searcy, 2016). The idea of sustainable investing most commonly refers to the ability to maintain a certain level of financial performance over time (Woods & Urwin, 2010). The term is also sometimes used in a slightly different context and refers to the relationship between an investment and its environment. This idea assumes that the social, economic and natural environments can not only influence financial performance but can also be affected by investment decisions (Searcy, 2016). To account for this reciprocal relationship, the alternative definition of investment sustainability refers to a practice that does not compromise any of the resources it depends on. This concept of responsible investing requires directing resources into assets that display certain characteristics of sustainability (Diltz, 1995) which may include their social and environmental impact (Hill, Ainscough, Shank, & Manullang, 2007).

In this context, sustainable real estate appears to be an interesting asset class as it seems that its impact on its environment is relatively simple to evaluate. In addition, they offer an opportunity to hold tangible assets, which means that their ability to replicate the current financial performance in the future may be less volatile and offer returns which are traditionally considered as relatively stable against inflation (Hudson-Wilson, Fabozzi, & Gordon, 2003; Ibbotson & Siegel, 1984; Kuhle, 1987).

Although the ability of real estate investments to produce returns that are more replicable over time than profits from other assets simply due to their physical nature remains a subject of an academic debate (see Worzala & Sirmans, 2003 for a summary), they appear to play a key role in determining environmental and social sustainability of urban areas (Matisoff et al., 2016). There is also a growing body of literature that evaluates the economic performance of assets with certain sustainability characteristics and suggests that sustainable buildings appear to offer higher financial returns. This research shows that rental levels, capitalization rates and sale prices are positively affected by introducing sustainability features into a building (Eichholtz et al., 2013; Fuerst & McAllister, 2011a, 2011b). However, while the returns seem to be favourable, the level of investment into this type of assets does not seem to fully reflect this advantage and adoption of sustainable technologies in real estate is slower than many expected (Matisoff et al., 2016). It is important to notice that, researchers focus almost exclusively on return as an indicator of financial performance while the related risk appears not receive attention. Consequently, it would seem that very little is known about the financial risk associated with investing into sustainable properties. This article examines the risk related to the improved financial performance reported in real assets with sustainable features (Eichholtz et al., 2013; Fuerst & McAllister, 2011a).

Fuerst and McAllister (2011a) offer a comprehensive overview of why and how such buildings can create financial value and support their theories with empirical findings. Eichholtz et al. (2013) present a general theoretical summary of how sustainability should relate to profitability and use empirical evidence to show a positive impact. Critically, market efficiency implies that a superior return entails an increase in either investment efficiency or risk but neither study considers the impactions of the reported return premia on risk. Szumilo (2015) as well as Szumilo and Fuerst (2014) examine the idea of creating a financial benefit in sustainable office properties in more depth and show that properties with 'green' technologies in place can

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offer two types of economic benefits: a cost saving and a set of additional services delivered to tenants (reputational benefits, increased productivity etc.). This is an important distinction as the former assumes increased economic efficiency that offers benefits with no additional risk, while the latter implies an operational change which may entail exposure to market risk. This indicates that the proportion of the financial benefit that does not increase risk increases the economic efficiency of investing into sustainable buildings. For example reducing operating expenses by increasing operating efficiency allows generating consistently more income from the same amount of invested capital. The same logic could be applied to tenants of sustainable buildings if they increase their operating efficiency by increasing workforce productivity or lowering employee absenteeism levels (Heerwagen, 2000). Although the financial value of those benefits of sustainability need to be distributed between landlords and tenants (Szumilo and Fuerst, 2015) an economic surplus is generated regardless of market conditions. However, the second type of sustainability benefits attributed to certified buildings appears to be exposed to changes in how the market prices those attributes at the time of signing the lease. For example, the renal premium for the reputational benefit suggested by Eichholtz et al. (2013) will only materialize under certain conditions. In order to positively contribute to the corporate image of its tenants the certified building must meet certain criteria, such as matching the corporate social responsibility policies and goals of its occupier. As those policies change and evolve over time, space and industries so may the premium attached to sustainability (Cidell, 2009; Reed and Wilkinson, 2005). It is also possible that as new sustainability technologies are introduced in other buildings, the structure that is currently considered sustainable loses that status over time. The decisive point in time is the moment of signing a lease and the financial premium depends on how the tenant perceives the non-efficiency-related value of sustainability when they agree on the rent they would pay.

By building on the work of Szumilo and Fuerst (2014), it appears that introducing sustainability into a real property offers two types of benefits to its financial performance (see Table 1 for examples). First, economic efficiency improvements should attract an immediate improvement in financial performance which should not attract additional risk. Second, the additional services offered by sustainable buildings may attract additional demand. If buildings with sustainability features are valuable to tenants at the time of signing leases their rents will benefit from a premium. However, if those specific characteristics are not something occupiers are willing to extra for, there is no benefit. The third possibility is that tenants would rather lease space that is not sustainable, in which case certification would result in a discounted rent. The three scenarios result in a degree of uncertainty related to the both the magnitude and the sign of the financial impact of sustainability that is not related to operational efficiency.

The above discussion relates to all aspects of sustainability but conducting a robust empirical study requires a more accurate definition In fact, it is necessary for sustainability to be measurable, so that its different levels can be compared across buildings. However, even if a strict definition is adopted, measuring sustainability can pose significant challenges (Forberg & Malmborg, 2004). On the other hand, one of its subsets; energy efficiency, can be easily defined, measured and compared across buildings. It is also one of the key aspects of all sustainability measures applied in real estate (Eichholtz et al., 2013). The analysis of financial benefits of sustainability presented above can easily be applied to energy efficiency. The logic of the cost-saving benefit remains applicable as energy costs are usually a significant operating expense (Szumilo, 2015). The argument of increased productivity is also valid, as more efficient energy solutions can offer this benefit by creating a more natural and comfortable working environment (Abbaszadeh, Zagreus, Lehrer, & Huizenga, 2006). In addition, a reduction in CO2 emissions can offer reputational benefits and attract higher demand from environmentally-conscious market participants. Although the relationship between energy efficiency and reducing CO2 emissions is indirect, lowering energy consumption is an important element of both energy and environmental polices (Gillingham, Kotchen, Rapson, & Wagner, 2013). Since both types of sustainability benefits (business efficiency and increased demand) seem to persist when the definition is limited to energy efficiency, focusing this study on this aspect appears to offer an approach that can be theoretically based on the logic outlined above and tested on empirical data.

Table 1
Benefits of sustainability in real property.

	Investment efficiency	Additional demand
Examples	Energy efficiency, Increased workforce productivity	Reputational benefits, Reduced environmental impact
Time frame	Instant effect that continues over time	Varies over time
Dependency on market changes	Independent of actions of market participants	Depends on how the market values the additional services
Additional risk	None	Risk of changes in demand

2. Current literature

2.1. Hypothetical benefits and risks of green buildings

Although a rich body of literature documents the fact that sustainable buildings receive higher rents, the driver of that benefit remains elusive (Eichholtz et al., 2013; Fuerst & McAllister, 2011a, 2011b; Miller, Spivey, & Florance, 2008; Szumilo & Fuerst, 2014). One of the first studies to discuss the economic impact of sustainability is presented by Fuerst and McAllister (2011a) who provide a comprehensive discussion of how the market for office space and individual assets could be affected. They focus on the higher willingness of tenants to pay for additional features of the green buildings they rent and expect that this leads to a renal premium. This concentrates their discussion on the number of different benefits that an occupier may expect from a sustainable building and leads to the conclusion that if they are prepared to pay for those features the rent should be higher. The study also provides some quantitative evidence for this claim and reports that sustainable office buildings receive a consistent rental premium. The empirical method is based on the hedonic model applied to a cross section of 24,479 US office buildings. It reports a premium of between 4% and 5%. Critically, the study is one of the first to apply a method of identifying properties with sustainable features based on sustainability certification.

While Eichholtz et al. (2010) use a similar empirical approach to explore a cross sectional dataset of US buildings, their theoretical analysis focuses on the role of sustainability in corporate social responsibility polices and concludes that the rental premium can be explained by the a combination of cost savings, improved performance due to better working environment, corporate image effects and higher overall demand. Splitting the benefits into those four categories allows them to indicate that the financial risk may also be affected by sustainability but no analysis of this issue is presented. As already noted, another study that divides those benefits into categories is presented by Szumilo and Fuerst (2014) who choose to group them into cost savings and additional services. Although they argue that both effects are favourable, they note that they can affect rental levels differently and that the impact depends on lease terms. The study focuses on the cost saving and empirically measuring its impact on operational expense. Although it reports a rental premium it concludes that is unlikely that it is caused by lower operating expenses. This suggests that the additional services may be its primary driver. This notion is explored further by Reitchard et al. (2012) who theorize that it may be a result of both supply and demand for sustainable office space changing over time. For example, increased popularity of environmentally sustainable goods may be positively linked to demand for certified properties. Unless this change is matched by a shift in supply it will result in volatile prices. Although their analysis of the phenomenon in context of risk is limited, they test the stability of the rental premium over time and find considerable differences which suggest increased volatility.

2.2. Measuring financial risk in real estate markets

The traditional way of measuring financial risk is based on the concept of volatility. The standard deviation of observed values from mean values of a variable can be used as a measure of it predictability. The alternative is to use asset pricing models that estimate expected values and allow measuring deviations of observed values against that number (Ambec & Lanoie, 2008; Blitz et al., 2013). Most commonly, this approach measures volatility against a benchmark. A good example is the capital asset pricing model which allows measuring the volatility of asset prices against the market. The later approach is widely adopted in real estate research that focuses on listed investment vehicles but focusing on volatility is more appropriate for analysing individual assets (Szumilo, Gantenbein, Gleißner, & Wiegelmann, 2016).

Various forms and specifications of asset pricing models are a popular research topic in finance and a large number of studies examine this issue by focusing on listed real estate funds (He, 2002; Hsieh & Peterson, 2000). In fact, recent research also considers the impact of including sustainable properties in a portfolio on trading prices of US Real Estate Investment Trusts (Eichholtz, Kok, & Yonder, 2012). The authors report an increased trading price but do not examine the related volatility or any other measures of risk. The challenge of using performance of a listed entity to examine characteristics of the assets it holds comes from the fact that over a short term real estate investment trusts tend to follow changes in the stock market rather than developments in the property market (Mueller & Mueller 2003; Myer & Webb, 1994).

An alternative risk indicator can be derived from a method of real estate asset valuation. As it relies on calculating the net present value of expected cash flows (Geltner, Miller, Clayton, & Eicholtz, 2007; Szumilo et al., 2016), financial performance of commercial office buildings can be linked to its characteristics. The expected net operating income is discounted using the capitalization rate. This denominator includes a premium for all risks of the estimated future cash flows. It incorporates sensitivity of individual structures to market risk as well as any property-specific risk factors. A positive influence of sustainability on the capitalization factor has been found by Eichholtz et al. (2010) as well as Miller et al. (2008). A study by Pivo and Fisher (2010) explains that expected changes in the expected income should be directly reflected in the capitalization rate. After considering possible effects of sustainability on those variables they show that both values are favourably affected by sustainability certification.

It is also possible to explicitly use volatility of rents as an indicator of financial risk in commercial property markets. McGough and Tsolacos (1999) show, on the example of the British property market, that this characteristic can be important not only in determining the investment uncertainty of a single building but also of the market as a whole. In addition, the authors conclude that information contained in historical volatility can be indicative of future financial performance of real assets. The rate of vacant space is also commonly used as an indicator of income risk in commercial office markets (Rosen, 1984; Shilling, Sirmans, & Corgel, 1987). In sustainable properties occupancy rates appear to be higher than in traditional buildings (Fuerst & McAllister 2011b; Miller et al., 2008). The theoretical foundation for this fact is best described by Wiley et al. (2008) who also show that higher occupancy rates related to sustainability can increase the accuracy of expected income estimates.

3. Study design

As acknowledged by the literature reviewed in the previous section, any empirical study that aims to measure the impact of sustainability certification on financial risk needs to be designed in the context of econometric challenges created by the unique features of real estate markets. This section discusses those issues and explains how they are addressed.

Changes in income do not necessarily affect value of assets directly but are affected by any corresponding adjustments to the capitalization rate which reflect alternations in income risk. Some evidence that capitalization rates are lower in sustainable buildings exists (Eichholtz et al., 2013; Fuerst & McAllister, 2011a, 2011b). However, little is known about the process of how individual components of this variable are affected. There is also no evidence that the positive changes to income levels occur at the same time as the reduction in capitalization rates. The objective of this study is to establish if changes to energy efficiency levels affect income risk and should, therefore, be reflected in the rate of its capitalization.

It is likely that the time of acquiring energy certification is not selected randomly, since before it occurs the building has to meet certain technological and operational criteria. Making sure that labelling standards are met may require advanced planning, preparation and possibly capital expenditure if improvements are required. If renovation is required to acquire the label, then it may be tempting to assume that certification usually occurs shortly after a major refurbishment. However, the sample used for this study shows that only around 5% of buildings that receive certification for the first time is newly refurbished (less than 2 years since refurbishment). This suggests that the decision to acquire the energy efficiency label is operational and its timing dictated by business rationale. This is consistent with the assumption that the value of certification varies with time and that landlords will choose to certify if they see an economic benefit of doing so. Consequently, it appears that it is likely that the financial benefits of energy certification that are associated with certification but not necessarily the actual level of efficiency determine the time of acquiring the label (Matisoff et al., 2016). However, there is a growing body of evidence that shows that certified buildings are in fact more energy efficient than non-certified structures and do consume less energy (Asensio & Delmas, 2017; Berardi, 2012; Blumberg, 2012; Diamond et al., 2006; Proto et al., 2007). This suggests that energy certified buildings receive the financial benefits that are related to both holding certification and higher energy efficiency. This conclusion is important for this research as it means that the empirical study has to capture both effects. The above analysis suggests that this can be achieved by focusing on energy certification. As the label can be used to signal the actual level of energy efficiency to the market, their reaction should be measurable in changes to financial indicators of the certifying building.

On the other hand, it is important to note that the informational content of certification may include more than just the level of energy performance. Since improving operational efficiency appears to be a straightforward economic decision, the certificate shows the quality of asset management and the attitude of the managers towards making optimizing improvements (Asensio & Delmas, 2017). Conversely, not having an energy certification label shows that the asset does not use its resources efficiently and chooses not to invest into profitable projects. This may raise questions about how the asset is managed and deter potential tenants. In addition, not investing into energy efficiency reveals a preference of the asset owner to prioritize short-term returns over long term sustainability. In this case, if a tenant can choose between two identical buildings that differ only in the level of energy efficiency (reflected in certification), then labelling can attract a premium for management quality as well as other sustainability benefits while the property that chooses not to invest into energy efficiency may be at risk of seeing its rents reduced. Chegut et al. (2014) discuss this phenomenon by considering the process by which certification spatially diffuses in office markets.

Some features of energy efficiency are expected to cause an immediate change in net cash flows. For example, an increase in energy efficiency can be expected to reduce operating costs. Assuming constant gross rental levels, this will immediately result in an increase in the net operating income. As this benefit comes from a change in economic efficiency, no adjustment to the capitalization rate should be expected. This premium should also remain constant regardless of the time horizon. However, this is not the case for the benefits related to the increased demand for efficient properties. In favourable market conditions, those may attract a higher rent but the premium is likely to vary over time as the environment changes. Due to this uncertainty the capitalization rate needs to be adjusted for the additional volatility of rents resulting from changing market conditions.

As outlined earlier, some changes in risk resulting from energy efficiency will not have a direct effect on net cash flows. For example, the reduced risk of having to comply with new environmental regulation is unlikely to be reflected in current rents or operating expenses. On the other hand, it reduces the expected rental volatility and operating costs. In consequence its impact on asset value should be positive due to a decrease in the capitalization rate.

If the expectation of a reduction in risk is true, this effect should be measurable, over a sufficiently long time period, as a decrease in actual volatility. In fact, all changes in risks, including those resulting from sustainability, can be expected to manifest themselves as immediate changes in capitalization rates. Such adjustment reflects changing expectations about future income streams. Over a sufficiently long time period, those expectations should materialize in actual values and be measureable as statistical properties of received cash flows. For example, long-term actual volatility of rents determines what the capitalization rate risk premium for this factor should have been at the beginning of the period.

The above discussion shows that the effect of sustainability on cash flows should vary over time and depend, at least partially, on market conditions. Over time, all components of risk are also realized in financial characteristics of income streams. Thus, by closely studying the behaviour of rental cash flows in certified assets over time, it is possible to investigate the relationship of risk and sustainability. While gross rents are not a perfect proxy for the net operating income, they can be a good indicators of changes in its value if they are adjusted for lease terms. Consequently, studying statistical characteristics of rent allows investigating the interaction of risk and profit in real property markets.

Two hypotheses follow from the above analysis. First, sustainable properties attract an immediate rental premium which depends on how the additional features are perceived and priced by the market. In this case, the financial effect comes from changes in demand for the space that becomes sustainable. The second hypothesis is that additional financial effects of sustainability come from higher economic efficiency of operating the real asset. In result, green buildings can generate higher returns per unit of input. This should offer a financial benefit at no additional risk. Empirical evidence can be obtained by analysing the results of the following tests:

1) Changes in the magnitude of the sustainability premium over time.

Estimating the reaction of rents to sustainability can give an idea of how the market is pricing such features at different points in time. Economic efficiency benefits should be reflected by an immediate adjustment to rental levels and not vary over time. However, other effects of sustainability will be exposed to changes in the market environment. Under favourable conditions, where agents are willing to pay more for green buildings, a premium can be expected. Should environmental features not be in demand, a discount (or no effect) is more likely to be found.

2) Differences in cash flow volatility between sustainable and traditional buildings over short and long terms.

After receiving a certificate, rents have to adjust to a new level. This can be associated with a process of searching for a new equilibrium and, therefore, increased volatility. Economic efficiency benefits are expected to create this effect shortly after first certification takes place but offer more stable rental values after that time. On the other hand, the effect of extra services may inflate short-term volatility persistently as it will always be exposed to changes in market conditions. Information extracted from rents over a short time period is valuable but offers little evidence about changes in the structure of cash flows that should be reflected in longer term projections of their values. As explained before, those are necessary in order to estimate capitalization rates. As the examination period lengthens the uncertainty that should have been included in the discount factor at the beginning materializes.

The two components of this research reveal critical information about the reaction of the key financial risk indicators of office buildings to holding energy efficiency certification. Looking at differences between effects in different years provides an insight into exposure to changes in market sentiments. Short-term volatility reflects not only the changing environment but also an adjustment to a new rental equilibrium. Long-term volatility shows structural changes to financial indicators that materialize over time.

4. Econometric methodology and data

This section empirically investigates the relationship of energy certification and statistical properties of rents. Specifically, it tests if introducing energy certification changes their risk profile. Financial risk is defined as uncertainty of rents and is approximated by their volatility. Two measures of volatility are used: standard deviations and changes in coefficients of independent variables over time.

4.1. Data

Detailed building-level information is provided by the CoStar Group Inc for all office properties available from their database. Changes are recorded on a quarterly basis over 30 time periods from Q2 2006 to Q3 2013. The dataset also includes information from the US Statistics Bureau on economic indicators at both local (unemployment rate) and national (US consumer price index) levels. It is also cross-referenced with the information available from the EnergyStar website and for all certified buildings in the sample the dataset includes values for the time of certification and a corresponding level of energy performance.

Geographical market selection is based on popularity of sustainable buildings as reported by EnergyStar in 2013 and this criterion is interpreted in two different ways: 1) the highest proportion of certified buildings to the total population of properties indicates Los Angeles and Houston as ideal candidates 2) the highest total number of certified properties points to Chicago and Denver. These four locations provide variations in climate conditions and industry composition that are appropriate for a large study. However, the Los Angeles market is closely linked to its surrounding property markets of Orange County, therefore, Orange County is also included in the sample. A full list of variables included in the sample and their key summary statistics are available in the Appendix A (Tables A1 and A2).

An overview of differences in rent between certified and non-certified buildings is (see Table A3 in Appendix A) shows that energy efficient buildings have, on average, higher rents. In addition this premium increases with the level of certification. However, one of the most significant criticisms of the methods used in sustainable real estate research is that it is difficult to isolate the impact of sustainability form other building-specific characteristics. In fact, Robinson and Sanderford (2015) show that sustainable buildings are likely to be structurally different from non-certified properties. In this context, the data collected for this research is particularly interesting as it tracks buildings over time and observes changes in energy efficiency features of particular structures.

4.2. The certification premium over time

Various models of rents are used in the literature to examine how sustainability affects their levels. Fuerst and McAllister (2011b) present a discussion of the issue and, as most other researchers, apply the hedonic pricing model (Rosen, 1974). In order to be able to externally validate its results, this study builds on this approach and applies this model to price the impact of energy efficiency certification on average rental values. However, the dataset collected for this study includes observations repeated over time which allows an important modification to the commonly estimated models. Including dummy variables that control for certification in a particular period isolates the value of the sustainability premium in different years. Reitchard et al. (2012) use this approach in a fixed-effects model to analyse a similar sample of 40 quarterly observations starting in 2004. Very similar results are obtained when their approach is replicated and applied to the data collected for this study. However, robustness tests show that this approach is biased by severe serial autocorrelation. In order to address this problem this study applies an autocorrelation-corrected estimation procedure (Baltagi and Wu, 1999) and modifies the model used by Reitchard et al. (2012) by converting the quarterly data into annual averages and using a random-effects panel model. Although the Hausman test (1978) indicated that outperformed the fixed-effects alternative using fixed effects exposed the model to the bias of unobserved fixed effects. As these are a considerable concern in modelling real estate prices this study applies a method of controlling for their impact suggested by Papke and Wooldrigde (2008) and estimates a correlated random effects model with time-averages of rental levels and vacancy rates added as independent variables:

$$y_{it} = \alpha + \beta X_{it} + \gamma \overline{X_i} + \varepsilon it \text{ with } i = 1, \ldots, N, \quad t = 1, \ldots, T \tag{1}$$

where y is the dependent variable taking values of the observable rents, X_{it} is the vector of explanatory variables that determine rents, $\overline{X_i}$ is the vector of time-averages of selected variables, i and t denote an entity and time period respectively, ε_{it} denotes the usual error term.

4.3. Rent volatility

Volatility is usually measured by statistical variance which means that it is always positive and can cluster close to zero. This makes it difficult to estimate it using linear models the assumption of normal distribution is likely to be violated. Although linear models are sometimes applied to estimate the relationship of volatility with their expected determinants, this approach has a number of limitations (Allen & Rachim, 1996; Nazier et al., 2010). An alternative is to use MLE estimators which do not assume that the dependent variable is normally distributed and using Tobit models has a long history of being applied to modelling financial risk defined as variance (Green, Maggioni, & Murinde, 2000; Knopf et al., 2002; Smith and Pitts 2006). Chavas and Kim (2004) show how to apply this approach to modelling variance and this study follows their recommendation.

Additional challenges of modelling variance include its tendencies to follow an autoregressive process and cluster around time periods (Bollerslev, Chou, & Kroner, 1992). To adjust for these time-series properties of the dependent variable an ARCH model can be used. However, using this estimation approach requires a long time series and limits the ability of the model to accurately reflect the relationship of variance to independent variables as it focuses on autocorrelation (Chavas and Kim 2004). Focusing on time series features of the modelled variable may also make it more difficult to control for differences between individual entities included in the dataset. To address this challenge some researchers use a different approach and apply various forms of heteroskedasticity-adjusted linear regressions which allow capturing different components of volatility. Naturally, this reduces the ability to accurately capture autocorrelation but this is not an issue if the bias it creates in estimates of the remaining determinants of volatility is adjusted for (Cohen, Okuda, Robert Schwartz, & Whitcomb, 1976; Duong & Kalev 2008; Ncube, 1996; Walls, 1999). The panel data used in this study has a large number of heterogenetic entities and relatively few time periods. Consequently, the estimation approach needs to reflect this structure and concentrate independent variables that affect volatility.

To adjust for within entity clustering, a panel Tobit model is adopted. The Harris–Tzavalis test shows no evidence of a unit root in standard deviations of rents but further tests indicate autocorrelation in this variable. The estimated standard errors are adjusted for this clustering by using the Bootstrap method (Berg & Coke, 2004; Petersen, 2009). Testing different alternatives by following a procedure suggested by Calzolari and Magazzini (2008) shows that a random-effects panel Tobit regression is optimal for this study and the Hausman test (1978), confirms this specification. Finally, a correlated random effects Tobit panel model of the following specification is used:

$$\begin{aligned} &\text{st. } dev_{it}^{*} = \beta X_{it} + \varepsilon_{it} + \alpha_i \\ &\text{vst. } dev_{it} = \max\{st.\ dev_{it}^{*}, 0\} \\ &\text{with } i = 1, \ldots, N, \quad T = 1, \ldots, T \end{aligned} \tag{2}$$

where st.dev is the observed dependent variable (in this case standard deviation of rents) for entity i in time t which only takes positive values, Xit is the vector of the independent explanatory variables for entity i in time t, β is the vector of coefficients and both ε_{it} (representing an error term for entity i in time t) and α_i(representing an overall error term for entity i) are assumed to be independently normally distributed.

Using cross sectional data for the study of long-term effects allows adopting a simpler estimation procedure. As discussed previously, a hedonic model of the following form can be adopted to estimate prices:

$$y_i = \alpha + \beta X_i + \varepsilon_i \text{ with } i = 1, \ldots, N \tag{3}$$

where y is the dependent variable taking values of the observable rents, X_i is the vector of explanatory variables that determine rents, i denotes an entity,ε_i denotes the usual error term.

This method controls for the measurable differences between properties in the starting period and detects their influence on rents. While it has a very limited ability to control for unobservable differences between structures it offers a time horizon of unprecedented length. Naturally, its results need to be interpreted in this context. A simple Ordinary Least Square (OLS) regression with appropriate dummy variables can be used to estimate the average long-term rental levels, however, modelling long-term volatility requires a non-linear model. A Tobit model is used to estimate a variance equation of the following form:

$$\begin{aligned} &var_i^{*} = \beta X_i + \varepsilon_i \\ &var_i = \max\{var_i^{*}, 0\} \\ &\text{with } i = 1, \ldots, N \end{aligned} \tag{4}$$

where var is the observed dependent variable (in this case 7 year variance of rents) which only takes positive values, Xi is the vector of the independent explanatory variables, β is the vector of coefficients, and the ε_i's are assumed to be independently normally distributed.

5. Results

Table 2 shows selected results for regression models relating energy certification variables to average rental levels. It uses dummy variables to show the effect of holding energy certification in any year (column 1) and an interaction term of this variable with dummy variables with the year of measurement to show the change in the effect over time (column 2). In both cases properties that do not hold certification are used as a benchmark.

Overall, the results indicate no unexpected relationships and are similar to findings of comparable pieces of research (see the literature review). Values of the goodness-of-fit statistics are satisfactory and indicate that the models can explain a significant proportion of the variance. The base case for lease terms is a gross lease and dummy variables were included if contract terms were different at the beginning of the examined period. As a result, all lease terms variables have negative coefficients.

Table 2
Selected results of a correlated random effects regression estimation for average annual rental values in the period from 2006 to 2013.

	1. The average effect of holding certification.			2. The impact of certification in different years.		
Estimation	GLS Correlated random effects			GLS Correlated random effects		
Dep. Variable	Ln(Average Annual Rents)			Ln(Average Annual Rents)		
Var. name	Coeff.	z-stat.		Coeff.	z-stat.	
Holds certification	0.006	*1.82*	*			
Certification in year						
2006				− 0.096	*−7.22*	***
2007				0.028	*3.22*	***
2008				0.048	*7.01*	***
2009				0.010	*1.65*	*
2010				−0.020	*−3.51*	***
2011				−0.009	*−1.47*	
2012				0.009	*1.56*	
2013				0.021	*2.1*	**
Control variables						
Lease type	*Yes*			*Yes*		
Economic	*Yes*			*Yes*		
Property char.	*Yes*			*Yes*		
Market Location	*Yes*			*Yes*		
Model statistics						
R-squared	0.7633			0.7634		
within	0.0421			0.0427		
between	0.8726			0.8726		
Wald chi2	100334.99			100495.1		

Notes: This table reports the correlated-random-effects model for average annual rental values (in $ per square foot) in the period from 2006 to 2013, estimated using the General Least Square method corrected for first-order autocorrelation (Baltagi and Wu, 1999).***, **, * indicate significance at the 1%, 5% and 10% level respectively. The model is estimated using STATA. Full results are available in Table A4 in Appendix A.

If energy certification is included as a dummy variable which corresponds to periods when the property holds certification, the effect is significant and positive. However, the premium is only 0.6% which is significantly less than values reported by other studies. Moreover, the coefficient is only marginally significant. This indicates that this may not be an optimal method of modelling the value of the certification premium when multiple time periods are taken into account. Nevertheless, it is important to note that the average effect of introducing energy efficiency certification in the analysed sample is statistically significant and positive.

Since other studies have found different values of the certification premium using cross sectional data, it would appear that using an average effect may not be the most appropriate method for a panel dataset. In order to allow for different effects in different periods, the energy efficiency dummy variable was divided into subcategories based on years of measurement. Respective coefficient estimates presented in Table 2. Table 2 show that the time of holding the certification can have a significant influence on its financial effect. Overall, the effect of certification is significant and varies from −9.6% to 4.8%. There seems to be a significant relationship between the time of measuring the effect of certification on rental values and the result. There also appears to be a considerable variance in the magnitude of the energy efficiency premium. Although the time series is not very long, a cyclical pattern can be identified (see Fig. 1). From a large discount in 2006, the effect of energy certification increases for two consecutive years. A decrease in the magnitude of the premium follows for the same amount of time. Two years of no effect occur next and a premium is recorded again in 2013. While drivers of those differences cannot be inferred from the analysis, they are clearly period-specific. Moreover, the cyclical pattern indicates that variations are not random but are related to endogenous changes that occur over time.

Interestingly, the level of energy certification has not been found to have an impact on the results. This indicates that the variation in the financial effect is not related to the actual level of efficiency. The financial impact of the actual level of energy efficiency seems not to be determined by market conditions.

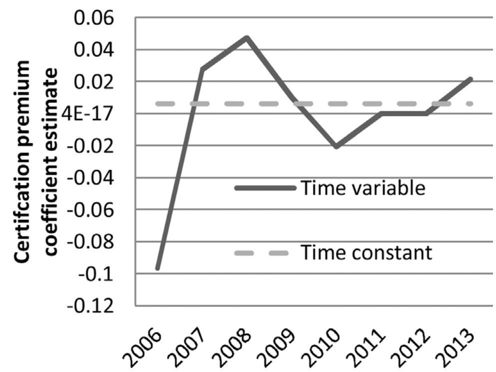

Fig. 1. Average versus time-variable coefficient estimates of the financial effect of energy efficiency.

The results are consistent with the hypothesis of the energy efficiency premium being exposed to changes in the market sentiment. In fact, they also support the claim that only the financial benefits related to additional services suffer in this way. However, the findings do not show if business efficiency improvements experience the same problem.

It would appear that on average sustainability attracts a rental premium. However, the effect is significantly exposed to contemporary changes in market sentiment. In fact, in some years it would seem that energy certified properties were leased at a discount. Therefore, it may be concluded that sustainability is indeed associated with an average rental premium, although this depends on market conditions and can be volatile.

Table 3 shows selected results for regression models relating energy certification variables to average short-term deviation from the mean rental value. Complete results are available in the appendix. Relatively little research that focuses on property-specific determinants of rental volatility is available as academics usually consider it to be determined exogenously (Buetow & Albert, 1998; Orr et al., 2003). This makes external validation of the detailed estimates of the model difficult. However, the presented results are consistent with expectations and relationships reported by other real estate researchers. For example, lease terms are significantly correlated with volatility and the triple net lease with its lowest values. This indicates that contracts that include only the basic rent are likely to vary less than ones that offer additional services. At the same time, higher rents are likely to vary less, especially in buildings with high levels of occupancy, which is consistent with the rental adjustment process presented by Hendershott et al. (1999, 2002). Volatility is also related to factors that are exogenous to buildings, such as economic variables including the CPI factor, interest rates and unemployment. All of these are negatively correlated to the dependent variable and show that as economic conditions deteriorate, rents are less volatile. This is consistent with the findings of Orr et al. (2003) who conclude that landlords are more likely to offer non-price incentives (rent-free periods or rent break clauses) than reduce asking rents. Consequently, the downward adjustment of rental values is slower than their upward correction which results in economic conditions correlating positively with rental variance. The fact that rental volatility reacts to overall market conditions finds further support in the fact that it is positively correlated to bond prices. As fixed income securities can reflect the overall risk of capital markets they indicate how its changes affect renal volatility.

The influence of energy efficiency variables on annual volatility is statistically significant. On average, rental values are less volatile in properties that hold energy certificates. However, buildings that have received certification for the first time show increased annual volatility. Although not presented in the above table, testing for correlation between the level of certification with the short-term volatility showed no statistically significant relationship.

The results suggest that, on an annual basis, rents are likely to be less volatile in energy certified properties. This is consistent with the hypothesis that energy certification lowers some short term risks, such as exposure to volatility in energy prices. In fact, the results suggest that

Table 3
Selected regression results for volatility of rental values.

Estimation method	Correlated random-effects panel Tobit		
Dep. Variable	Average Annual Standard Deviation of Rents		
Var. name	Coeff.	z-stat.	
Holding certification	−0.654	*−2.09*	**
Years since first certification			
0	0.951	*2.92*	***
1	0.768	*2.28*	**
2	0.523	*1.5*	
3	0.343	*0.92*	
4	0.314	*0.78*	
5	0.368	*0.81*	
6	−0.249	*−0.08*	
Control variables			
Lease type	*Yes*		
Economic	*Yes*		
Property char.	*Yes*		
Location	*Yes*		
Model statistics			
Log likelihood	−120663.11		
Wald chi2	14122.55	***	

This table reports the Tobit correlated-random-effects model for annual volatility of rental values in the period from 2006 to 2013, estimated using the General Least Square method. The estimated standard errors are estimated using the bootstrap method to correct for autocorrelation (Mantalos and Shukur 2008).***, **, * indicate significance at the 1%, 5% and 10% level respectively. The presented standard errors are estimated using the Bootstrap method (Guan 2003) and investigated for any deviation from the assumptions of independent normal distribution. No issues were identified. An examination using the link test (Tukey, 1949) showed no evidence of misspecification of the functional form of the dependent variable. The model is estimated using STATA. Full results are available in Table A5 in Appendix A.

this outweighs the negative effect of the short-term volatility of adjusting to the new rental level that follows certification. It would appear that, despite the fact that the certification premium is exposed to market risk, the overall short term rent volatility is reduced by energy certification. However, this benefit does not materialize immediately after becoming certified as the first two periods of holding certification are associated with increased rental variability. This could be a result of an adjustment resulting from reflecting the sustainability premium in rent. As rental rates are expected to be different in certified properties (Eichholtz et al., 2013; Fuerst et al., 2011a, 2011b) it is likely that the process of adjusting to the new equilibrium can attract some volatility.

Overall, the results presented in Table 3 indicate that any financial benefits of certifying a building come at the expense of increased initially volatility. The rent adjusts to a new level as soon as the property becomes certified but remains more stable after that. Consequently, its volatility increases initially but after two years is reduced to below its values in comparable non-certified structures.

Table 4 presents selected results for models of long-term average rents and their volatility. They are estimated using starting period values as independent variables but also include time averages of key indicators to control for structural differences between buildings. Since rents often display autoregressive patterns starting period values are a significant indicator of long-term averages. Another important structural indicator is location which reflects regional property market cycles and the volatility that results from changing local economies. Higher starting unemployment correlates to lower long-term volatility. This suggests that rents vary less in counties with high unemployment, which is consistent with the practice of landlords offering non-monetary incentives before reducing rents. Most property characteristics included in the models are significant which indicates that long-term volatility is affected by structural differences between buildings. For example class A offices seem to experience more variability in their rents than other building types. Structural variables that can change over time, such as lease terms, are also significant although only three lease types influence long-term volatility differently than a gross contract. Negotiable terms seem to be associated with the largest increase in the dependent variable. This is consistent with the expectation that this type of contract correlates to the biggest variances between individual agreements within a building. Although the model can explain less than 4% of changes in the dependent variable, the results seem to be consistent with expectations and the economic theory of changes in rents.

The table reports two types of controls for energy certification: a dummy variable for holding certification and a semi-continuous variable reflecting its score. Critically, no effect of energy certification is found. Neither the fact of receiving a certificate nor its level are found to be correlated to long-term volatility. It appears that average long-term rental volatility is not affected by certification at the beginning of the period.

It is possible that the figures presented in Table 4 may be influenced by econometric challenges outlined earlier in this section. In order to ensure that these do not dominate the results, alternative specifications were explored (although are not presented in this study). Varying the estimation time period and using six, five and four years allowed increasing sample size and testing different starting periods. Applying fixed-effects estimation methods to two three year subsamples allowed controlling for heterogeneity across individual buildings. All alternative econometric specification yield results similar to those presented in Table 4 and point to the conclusion that energy efficiency has no impact on long-term volatility of rental values.

Table 4 also shows the results of modelling the average level of rent over a seven year period as a function of starting period's variables. The magnitude of the reported long-term effect of certification is comparable with findings of other studies (Eichholtz et al., 2013; Fuerst & McAllister, 2011b) but has the advantage of considering significantly longer time horizons. Based on the highest and the lowest values of energy certification found in the sample its total effect on rent ranges from −$1.42 to $3.08 (assuming a gross lease). Three key findings seem to emerge from Table 4. The first is the conclusion that certification is an important determinant of average long-term rent. The second is that certification score is a statistically significant determinant of its financial impact. The third is the fact that the financial effect may take the form of a discount as well as a premium. Critically, it appears that receiving an energy label is a significant event in the life of an office building and has a lasting impact on its financial performance. The fact that the level of certification is important in determining the sign of the effect on income suggests that the actual level of efficiency is important. A higher efficiency score seems to correspond to a larger rental premium but attracts no changes in volatility. This is consistent

Table 4
Selected regression results for long-term volatility and rental values.

Estimation Dep. Variable Var. name	Tobit Standard deviation MPE	Ordinary Least Squares Rent Coefficient
Holds certification	−0.31	−14.86*
	−0.34	*−1.93*
Certification score	0.007	0.18**
	0.55	*2.05*
Control variables		
Lease type	*Yes*	*Yes*
Economic	*Yes*	*Yes*
Property char.	*Yes*	*Yes*
Location	*Yes*	*Yes*
Model statistics		
left-censored	2086	
uncensored	12309	
Log likelihood	−29568.7***	
Wald chi2	1383.55***	
R squared		0.675
F statistic		333.64

This table reports a Tobit model for average volatility of rents and an Ordinary Least Squares model for average rental values over a 7 year period from 2006 to 2013. The standard errors estimated for both models are robust to heteroskedasticity using the Huber/White error estimation (Huber, 1967, White, 1980).***, **, * indicate significance at the 1%, 5% and 10% level respectively. The model is estimated using STATA. Full results are available in Tables A6 and A7 in Appendix A.

Table 5
Qualitative summary of empirical results.

Investigated effect	Finding	Income conclusion	Risk conclusion	Hypothesis test
Changes in the magnitude of the sustainability premium over time.	The effect of holding certification changes between years but on average is positive.	On average, rental income increases with certification. However, in some years discounts were found.	The immediate "premium" incorporated in rental values after certification is exposed to market risk.	The rental level effect is immediate and significant but varies over time so hypothesis 1 cannot be rejected.
The difference in short-term cash flow volatility between sustainable and traditional buildings.	Short term volatility is lower in certified buildings after two years since certification.	Adjustments to rent start immediately after certification and take two years.	Annual variability of rents is reduced two years after certification.	After the first two years certified buildings have lower volatility so short term hypothesis 2 cannot be rejected.
The difference in long-term average cash flows and their volatility between sustainable and traditional buildings.	Certification can be related to a premium but it depends on its level. Volatility seems unaffected.	A long term increase in the average rental income depends on the level of energy efficiency.	There seems to be no increase in the long term volatility of rental income in certified properties.	Long term rent/volatility ratio is higher in certified buildings so long term hypothesis 2 cannot be rejected.

with findings of other researchers (Eichholtz et al., 2013; Fuerst & McAllister, 2011b) but also with the hypothesis that benefits of energy efficiency can be related to increased business. This efficiency should manifest itself in higher rental levels and lower (or unchanged) volatility, which is supported by the empirical results presented above. On average, income per unit of volatility is higher in energy certified buildings. This indicates that as the time horizon lengthens, the financial gains from energy certification are increasingly reliant on economic efficiency.

5.1. Discussion

Table 5 presents a qualitative summary of the empirical results of all three models which provide evidence that the two hypotheses presented in Section 3 cannot be rejected. The first hypothesis (sustainable properties attract an immediate rental premium which varies over time) finds support in the results of the model of rental premia over time (row 1 in Table 5). The second hypothesis (additional financial effects of sustainability come from higher economic efficiency) is tested by the two volatility models summarized in rows 2 and 3 of Table 5. As both tests show that investment efficiency is higher in energy certified buildings the premise cannot be rejected.

The first empirical test of this study investigates the variability of the sustainability premium in rental values over time. Although a positive average effect of energy efficiency on income level is found, its magnitude changes significantly in different years. In fact, the variations are so large that both discounts and premia are reported. This supports the hypothesis that at least a proportion of the short-term effect of energy efficiency on income depends on the contemporary market environment which increases exposure to market risk. However, there is also a component of energy efficiency that affects income but does not increase risk exposure. An investigation of the short-term volatility showed that on average rents vary less in properties that hold energy certification. This indicates that, despite the volatility of the certification premium, energy efficiency reduces the short-term variability of the income stream. Interestingly, some evidence of a rental adjustment process is found in the first two years after certification. It appears clear that the effect of certification changes over time. While energy labelling correlates to lower annual volatility, modelling its long-term effects shows no relationship with risk. However, while volatility is unaffected a positive effect on rental level is found which confirms the expectation of a positive overall effect on income characteristics. However, the level of energy efficiency is shown to be critical in determining the magnitude and direction of the change. This indicates the importance of benefits related to the actual level of efficiency.

6. Conclusions

The study examines the financial risk related to increasing energy efficiency of office buildings. Since other researchers report significant value and rental premia after improving energy performance, this paper examines if they are an effect of increased investment efficiency or greater risk exposure. It develops and tests two hypotheses: 1) energy efficient properties attract higher demand which depends on market conditions and increases exposure to market risk 2) some financial effects of energy efficiency are related to higher economic efficiency and do not attract additional risk. Empirical results support both statements and are consistent with findings of other scholars. Statistical characteristics of rental levels appear to be different in buildings that hold energy certification.

The average effect over the investigated period is a small premium but significant variations are found between different years. Buildings with sustainability features seem to attract higher average rents at no additional long-term risk and with reduced short-term volatility. This is likely a result of the higher demand for space with sustainability characteristics and increased business efficiency of operating such properties. Rental rates adjust to the new level over two years of increased volatility. After that period there are no adverse effects on overall uncertainty, despite the fact that the rental premium is sensitive to market conditions. In the long run, this translates into an increase in average rental values which is not accompanied by additional risk. In summary, it appears that improving energy efficiency of an office building improves its overall investment efficiency despite exposing it to additional market risk.

Appendix A. Full regression results

Table A1
List of variables.

Location	
chicago	Located in Chicago
houston	Located in Houston
denver	Located in Denver
Lease contract type dummy variables[a]	
mg	Modified gross contract
elec	Net contract plus electricity

(continued on next page)

Table A1 *(continued)*

util	Net contract plus all utilities
cle	Net contract plus cleaning
nnn	Triple net contract
nn	Double net contract
n	Net contract
mix	Mixed contracts available
neg	Negotiable contract terms
ec	Net contract plus electricity and other charges
charg	Net contract plus charges
Time variable property-specific characteristics	
vacancy	Current rate of vacancy
rent	Current asking rent in $ per square foot
Ln(rent)	Natural logarithm of rent
RBA	Rentable Building Area in square feet
Time invariable property-specific characteristics	
class A	Class A office building
Class B	Class A office building
age	Age in number of years
age2	Squared value of age
age3	Cubed value of age
stories	Number of stories
elevators	Number of elevators
atrium	Building has an atrium
restaurant	Building has a restaurant
security	Building has security facilities
banking	Building has banking facilities
courtyard	Building has a courtyard
for sale	Building is for sale
air con.	Building has air conditioning
card access	Building has card access
food	Building has a food court
conference	Building has conferencing facilities
on-site mgmt	Building has on-site management
dry cleaning	Building has dry cleaning facilities
Energy certification variables	
ES certified	Building is energy certified
Years since certification	Number of years since energy certification
ES score	EnergyStar certification score
cert20XX	Building holds certification in year 20XX
Time average variables	
1y vac. avr.	Annual average vacancy
LT vac. avr.	Full sample average vacancy
LT RBA avr.	Full sample average RBA
LT rent avr.	Full sample average rent
1y rent avr.	Annual average
1y bond price avr.	Annual average 10y US gov. bond price
Economic environment variables	
CPI factor	US Consumer Price Index factor
CPI index	US Consumer Price Index factor
unemployment	The rate of unemployment (county level)
bond price	Current 10y US gov. bond price
1y bond var.	Annual 10y US gov. bond price variance
Additional	
full year	Measurement year includes four quarters (all apart from 2006 and 2013)
constant	Regression constant term

Dummy variables are in italics.

[a] Some categories of individual lease terms may seem overlapping. Nevertheless, they have been kept separate in order to reflect the view of the selling party on the differences.

Table A2

Summary statistics of selected non-dichotomous variables.

2006 values		N = 14395	Time periods = 1	
	Average	St. Dev.	Min	Max
Rent	19.28813	8.310138	0.04	102.84
Vacancy	0.1283585	0.2215222	0	1
Unemployment	4.797951	0.5202587	3.8	6.6
Building Area	53177.64	128389.8	500	3781045
Age	37.98249	25.14557	2	188
Quarterly average values		N = 417455	Time periods = 29	
Rent	**19.46315**	**8.518189**	**0.04**	**102.84**
between		8.06227	0.2	102.84
within		2.750218	−26.6841	82.71694

Table A2 *(continued)*

Quarterly average values		N = 417455	Time periods = 29	
Vacancy	**0.1650085**	**0.2551479**	**0**	**1**
between		0.1611641	0	1
within		0.1978088	−0.80051	1.130526
Unemployment	**8.058157**	**2.76881**	**3**	**19**
between		1.458899	5.482759	11.74138
within		2.35331	0.616778	15.31678
Building Area	**53177.13**	**128385.7**	**500**	**3781045**
between		128390	500	3781045
within		27.95133	51646.44	60524.44
Age	**37.98353**	**25.14456**	**2**	**188**
between		25.14534	2	188
within		0.0566709	23.08698	41.08698

Overall- values for the whole sample and all observations. Between – average values for individual properties. Within- values for deviation from mean of individual property with the global average added back in (see STATA manual for details).

Table A3
Average rent for different subsamples.

	Certified vs. Non-certified			Energy certification levels					
	All	Non-certified	Certified	ES75	ES80	ES85	ES90	ES95	ES100
Mean	19.34	19.17	24.88	23.43	23.16	24.16	24.53	26.96	27.18
St.Dev	8.34	8.26	9.11	9.84	7.97	8.88	9.30	9.65	8.58
Observations	364,636	353,843	10,793	582	2173	2350	2412	2199	1077

This table reports the correlated-random-effects model for average annual rental values (in $ per square foot) in the period from 2006 to 2013, estimated using the General Least Square method corrected for first-order autocorrelation (Baltagi and Wu, 1999). The model is estimated using STATA.

Table A4
Results of a correlated random effects regression estimation for average annual rental values in the period from 2006 to 2013.

Estimation	RE GLS regression with AR(1) disturbances							
Dependent variable	Ln(average annual rent)							
Variable	Dichotomous energy certification				Interaction between certification and the year of measurement			
	Coef.	Std. Err.	z–stat	P > |z|	Coef	Std. Err.	z–stat	P > |z|
LT RBA avr.	−0.000012	0.000002	−5.94	0.0	−0.00001	0.000002	−5.94	0.0
1y vac. avr.	0.0689	0.0125	5.5	0.0	0.0693	0.0125	5.54	0.0
LT rent avr.	0.0450	0.0002	240.4	0.0	0.0450	0.0002	240.42	0.0
LT RBA avr.	0.000012	0.000002	5.95	0.0	0.000012	0.000002	5.96	0.0
full year	−0.0096	0.0013	−7.22	0.0	−0.0095	0.0014	−7.06	0.0
mg	−0.0198	0.0020	−10.15	0.0	−0.0198	0.0019	−10.16	0.0
elec	−0.0693	0.0059	−11.69	0.0	−0.0694	0.0059	−11.72	0.0
util	−0.0274	0.0050	−5.53	0.0	−0.0275	0.0050	−5.55	0.0
cle	−0.3334	0.0181	−18.44	0.0	−0.3335	0.0181	−18.46	0.0
nnn	−0.0470	0.0014	−32.45	0.0	−0.0471	0.0014	−32.5	0.0
nn	−0.0851	0.0206	−4.14	0.0	−0.0851	0.0205	−4.14	0.0
n	−0.0682	0.0045	−15.11	0.0	−0.0684	0.0045	−15.16	0.0
mix	−0.0350	0.0069	−5.11	0.0	−0.0361	0.0069	−5.25	0.0
neg	−0.2973	0.0048	−61.35	0.0	−0.2971	0.0048	−61.37	0.0
ec	−0.0880	0.0131	−6.72	0.0	−0.0881	0.0131	−6.73	0.0
charg	−0.1138	0.0252	−4.51	0.0	−0.1137	0.0252	−4.51	0.0
vacancy	0.0114	0.0041	2.81	0.0	0.0113	0.0041	2.78	0.0
1y bond price avr.	0.2878	0.0304	9.48	0.0	0.2738	0.0305	8.97	0.0
1y vac. avr.	−0.1093	0.0110	−9.91	0.0	−0.1095	0.0110	−9.93	0.0
CPI index	−0.0012	0.0001	−11.5	0.0	−0.0012	0.0001	−11.48	0.0
unemployment	−0.0032	0.0005	−6.97	0.0	−0.0031	0.0005	−6.65	0.0
bond price	0.0312	0.0029	10.61	0.0	0.0300	0.0030	10.16	0.0
air con.	−0.0201	0.0088	−2.29	0.0	−0.0200	0.0088	−2.29	0.0
card access	0.0326	0.0058	5.58	0.0	0.0323	0.0058	5.53	0.0
food	0.0096	0.0054	1.77	0.1	0.0099	0.0054	1.83	0.1
conference	0.0190	0.0050	3.81	0.0	0.0186	0.0050	3.73	0.0
on-site mgmt	−0.0095	0.0039	−2.43	0.0	−0.0092	0.0039	−2.36	0.0
dry cleaning	−0.0337	0.0119	−2.84	0.0	−0.0330	0.0119	−2.78	0.0
class A	0.0199	0.0051	3.87	0.0	0.0205	0.0051	3.98	0.0
Class B	0.0453	0.0028	16.42	0.0	0.0453	0.0028	16.42	0.0
chicago	−0.0104	0.0037	−2.77	0.0	−0.0104	0.0037	−2.78	0.0
houston	−0.0302	0.0046	−6.58	0.0	−0.0299	0.0046	−6.5	0.0
denver	−0.0430	0.0039	−10.98	0.0	−0.0428	0.0039	−10.92	0.0
ES certified	0.0064	0.0035	1.82	0.1	–	–	–	–
cert2006	–	–	–	–	−0.0964	0.0134	−7.22	0.0
cert2007	–	–	–	–	0.0277	0.0086	3.22	0.0
cert2008	–	–	–	–	0.0476	0.0068	7.01	0.0
cert2009	–	–	–	–	0.0103	0.0062	1.65	0.1
cert2010	–	–	–	–	−0.0205	0.0058	−3.51	0.0
cert2011	–	–	–	–	−0.0095	0.0064	−1.47	0.1
cert2012	–	–	–	–	0.0092	0.0059	1.56	0.1
cert2013	–	–	–	–	0.0215	0.0102	2.1	0.0
constant	−0.7926	0.2755	−2.88	0.0	−0.6766	0.2769	−2.44	0.0
Number of obs				115160		115160		
Number of groups				14395		14395		
Obs per group				8		8		
R squared:		within		0.0421		0.0427		
R squared:		between		0.8726		0.8726		
R squared:		overall		0.7633		0.7634		
Prob > chi2				0		0		
Wald chi2(35)				100334.99		100495.09		asd

Table A5
Selected regression results for volatility of rental values.

Estimation	Gauss–Hermite quadrature random-effects Tobit regression			
Dependent variable	Annual standard deviation of rent			
Variable	Coef.	Std. Err.	z–stat.	P > |z|
Ln(rent)	−1.35838	0.076265	−17.81	0
vacancy	3.553047	0.127219	27.93	0
1y rent avr.	0.104614	0.004118	25.4	0
1y vac. avr.	−1.6381	0.139935	−11.71	0
LT RBA avr.	8.98E-08	2.84E-07	0.32	0.752
CPI factor	−4.66889	0.427648	−10.92	0
unemployment	−0.09993	0.011657	−8.57	0
full year	0.265155	0.042805	6.19	0
mg	0.170407	0.045075	3.78	0
elec	−0.23396	0.137908	−1.7	0.09
util	−0.22466	0.123125	−1.82	0.068
cle	1.483462	0.441941	3.36	0.001
nnn	−3.3078	0.0387	−85.47	0
nn	−0.64229	0.549854	−1.17	0.243
n	−0.68041	0.108009	−6.3	0
mix	−1.29334	0.171686	−7.53	0
neg	0.445221	0.134931	3.3	0.001
ec	0.280214	0.326171	0.86	0.39
charg	0.185395	0.576656	0.32	0.748
stories	0.052523	0.00645	8.14	0
elevators	0.021082	0.012292	1.72	0.086
class A	0.961415	0.070773	13.58	0
Class B	0.50662	0.041796	12.12	0
chicago	−0.52039	0.066826	−7.79	0
houston	−0.38043	0.077676	−4.9	0
denver	−0.08992	0.070684	−1.27	0.203
atrium	0.141684	0.074133	1.91	0.056
card access	0.174475	0.088939	1.96	0.05
restaurant	0.329163	0.076765	4.29	0
on-site mgmt	0.180491	0.053265	3.39	0.001
security	0.244988	0.090521	2.71	0.007
1y bond var.	1.883691	0.141863	13.28	0
bond price	−1.79424	0.123957	−14.47	0
ES certified	−0.6543	0.313422	−2.09	0.037
Years since certification				
1	0.950989	0.325926	2.92	0.004
2	0.767966	0.33734	2.28	0.023
3	0.523034	0.349638	1.5	0.135
4	0.343027	0.371646	0.92	0.356
5	0.314292	0.402537	0.78	0.435
6	0.367537	0.45453	0.81	0.419
7	−0.24868	2.992702	−0.08	0.934
constant	−3.04638	5.728069	−0.53	0.595
sigma_u	1.459307	0.020135	72.48	0
sigma_e	3.047787	0.012746	239.11	0
rho	0.186501	0.004323		asd
Observations				115160
left-censored				79284
uncensored				35876
Wald chi2(41)				14129.77
Prob > chi2				0
Log likelihood				−120657

Panel-level variance components are labelled sigma e and sigma u, respectively while the overall component is labelled rho. When rho is zero, the panel-level variance component is unimportant, and the panel estimator is not different from the pooled estimator.
This table reports the Tobit correlated-random-effects model for annual volatility of rental values in the period from 2006 to 2013, estimated using the General Least Square method. The estimated standard errors are estimated using the bootstrap method to correct for autocorrelation.

Table A6
Regression results for long-term rental values.

Estimation	Ordinary Least Squares			
Dependent variable	Average Long-Term rent			
Variable	Coef.	Std. Err.	z − stat.	P > |z|
rent	0.686079	0.016581	41.38	0
mg	−0.45021	0.153184	−2.94	0.003
elec	−0.20632	0.263677	−0.78	0.434
util	−0.93301	0.33974	−2.75	0.006
cle	1.882639	1.437549	1.31	0.19
nnn	−0.88279	0.091004	−9.7	0
nn	−1.11222	0.478907	−2.32	0.02
n	−0.19125	0.449619	−0.43	0.671
neg	2.820618	0.596955	4.73	0
ec	0.134143	0.850809	0.16	0.875
unemployment	0.072073	0.065365	1.1	0.27
class A	1.922489	0.207816	9.25	0
Class B	0.565957	0.092886	6.09	0
chicago	−1.02196	0.134731	−7.59	0
houston	−0.77218	0.169626	−4.55	0
denver	−1.16947	0.148399	−7.88	0
age	−0.04937	0.009691	−5.09	0
age2	0.000977	0.000168	5.82	0
age3	-4.37E-06	8.32E-07	−5.25	0
atrium	0.113904	0.162279	0.7	0.483
banking	−0.03194	0.183146	−0.17	0.862
restaurant	0.074235	0.212109	0.35	0.726
conference	−0.00946	0.1258	−0.08	0.94
on-site mgmt	0.325992	0.124243	2.62	0.009
courtyard	−0.09907	0.285193	−0.35	0.728
vacancy	−0.38709	0.142938	−2.71	0.007
RBA	4.10E-07	5.30E-07	0.77	0.439
stories	0.076495	0.013675	5.59	0
for sale	−0.4361	0.100702	−4.33	0
ES score	0.183686	0.089604	2.05	0.04
ES certified	−14.8649	7.691368	−1.93	0.053
constant	6.107559	0.533708	11.44	0
Observations				14395
F statistic				333.64
R-squared				0.6747

This table reports an Ordinary Least Squares model for average rental values over a 7 year period from 2006 to 2013. The standard errors estimated are robust to heteroskedasticity using the Huber/White error estimation (Huber, 1967, White, 1980).

Table A7
Regression results for long-term rental volatility.

Estimation	Tobit regression							
Dependent variable	Long-Term standard deviation of rent							
Variable	Coef.	Std. Err.	z − stat.	P > |z|	MPE[b]	Std. Err.	z − stat.	P > |z|
mg	0.038501	0.067582	0.57	0.569	0.020943	0.03691	0.57	0.57
elec	−0.33118	0.170023	−1.95	0.051	−0.1727	0.08521	−2.03	0.043
util	0.043161	0.142033	0.3	0.761	0.023506	0.07775	0.3	0.762
cle	2.589048	1.914359	1.35	0.176	1.829258	1.6394	1.12	0.265
nnn	−0.40659	0.043198	−9.41	0	−0.22197	0.0236	−9.41	0
nn	−0.02817	0.388289	−0.07	0.942	−0.01521	0.20903	−0.07	0.942
n	−0.06405	0.216727	−0.3	0.768	−0.03446	0.11574	−0.3	0.766
neg	1.442048	0.253841	5.68	0	0.912318	0.1829	4.99	0
ec	1.270757	0.778047	1.63	0.102	0.793423	0.55024	1.44	0.149
unemployment	−0.20241	0.041078	−4.93	0	−0.10969	0.02221	−4.94	0
vacancy	0.314501	0.215481	1.46	0.144	0.170432	0.11667	1.46	0.144

(continued on next page)

Table A7 *(continued)*

Estimation	Tobit regression							
Dependent variable	Long-Term standard deviation of rent							
Variable	Coef.	Std. Err.	z − stat.	P > |z|	MPE[b]	Std. Err.	z − stat.	P > |z|
class A	0.323852	0.096104	3.37	0.001	0.180677	0.0551	3.28	0.001
Class B	0.014454	0.046795	0.31	0.757	0.007832	0.02535	0.31	0.757
rent	0.121608	0.04791	2.54	0.011	0.065901	0.02599	2.54	0.011
LT vac. avr.	1.89281	0.150175	12.6	0	1.02574	0.08145	12.59	0
chicago	−0.32318	0.075569	−4.28	0	−0.17149	0.03893	−4.41	0
LT RBA avr.	0.000449	0.00018	2.5	0.013	0.000243	0.0001	2.5	0.013
1y rent avr.	−0.04549	0.048751	−0.93	0.351	−0.02465	0.02642	−0.93	0.351
1y vac. avr.	−0.97594	0.232658	−4.19	0	−0.52888	0.12568	−4.21	0
LT RBA avr.	−0.00045	0.00018	−2.5	0.012	−0.00024	0.0001	−2.5	0.012
houston	−0.7816	0.108661	−7.19	0	−0.39743	0.051	−7.79	0
denver	−0.4948	0.095575	−5.18	0	−0.26025	0.04829	−5.39	0
stories	0.03348	0.0081	4.13	0	0.018143	0.00437	4.15	0
atrium	0.258687	0.086181	3	0.003	0.143976	0.04905	2.94	0.003
card access	−0.17775	0.085595	−2.08	0.038	−0.09459	0.04453	−2.12	0.034
restaurant	0.232096	0.089576	2.59	0.01	0.128797	0.0509	2.53	0.011
conference	−0.23331	0.068523	−3.4	0.001	−0.12354	0.03537	−3.49	0
on-site mgmt	0.144102	0.058137	2.48	0.013	0.078976	0.03213	2.46	0.014
security	0.269462	0.120366	2.24	0.025	0.150176	0.06844	2.19	0.028
ES certified	−0.61069	1.962064	−0.31	0.756	−0.30844	0.92049	−0.34	0.738
ES score	0.012932	0.02332	0.55	0.579	0.007008	0.01264	0.55	0.579
constant	1.144877	0.276074	4.15	0				
/sigma[a]	2.247478	0.046159						
Observations								14395
left-censored								2086
uncensored								12309
Log pseudo likelihood								−29286.8
R-squared								0.0392
F statistic								47.77

This table reports a Tobit model for average volatility of rents over a 7 year period from 2006 to 2013. The standard errors estimated are robust to heteroskedasticity using the Huber/White error estimation (Huber, 1967, White, 1980).

[a] The parameter reported as/sigma is the estimated standard error of the regression.

[b] MPE denominates Marginal Partial Effects at change from 0 to 1 for dummy variables or at mean value for other variables.

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