Sustainable Development and Commercial Real Estate Financing: Evidence from CMBS Loans*

Xudong An
Federal Reserve Bank of Phialedephia
Xudong.An@phil.frb.org

Gary Pivo
School of Landscape Architecture and Planning
University of Arizona
gpivo@u.arizona.edu

July, 2016

* We thank Avis Devine, Nils Kok, Shimeng Liu, Pat McAllister, Paige Mueller, Joe Nichols, Doug Poutasse, Jim Shilling, Chaoyue Tian, Bob White and participants at the 2015 RERI Research Conference and the 2015 AREUEA National Conference for helpful comments. Financial support from the Real Estate Research Institute (RERI) is gratefully acknowledged. We are also grateful to Trepp, Real Capital Analytics, US Green Building Council and Redfin for providing invaluable data. Views expressed in this paper do not necessarily represent those of the Federal Reserve Bank of Philadelphia or the Board of Governors of the Federal Reserve System. Any errors and omissions are solely the authors' responsibility.

Abstract

Using a novel dataset that matches commercial mortgage and green building information, we study the impact of green development on the default risk, interest rate and other loan terms of commercial mortgage-backed securities (CMBS) loans. To identify the causal relation between green building status and loan default risk, we exploit both the cross sectional and the time series variations in Energy Star labeling and LEED certification of our CMBS properties, and estimate hazard models with longitudinal data. Our results show that office CMBS loans can have more than 30 percent reduction in default risk after the collateral property becomes Energy Star labelled or LEED certified. This difference is after controlling for other factors that affect default risk, such as mark-to-market loan-to-value (LTV) ratio and contemporaneous debt-service-coverage (DSCR) ratio, etc. A matched-sample analysis confirms the effect of green development. Our analysis also suggests that the impact at least partially come from enhanced property operating efficiency, instead of solely from the green label or certificate. All else equal, green property loans tend to have better loan terms than non-green property loans: they carry lower interest rate, and have significantly longer interest-only periods. However, our results cannot be generalized to retail CMBS loans.

Sustainable Development and Commercial Real Estate Financing: Evidence from CMBS Loans

1. Introduction

Sustainability has become an increasingly important theme in economic development, especially in the real estate industry. In addition to being socially responsible, going "green" can be economically beneficial. A number of papers have suggested that "green" buildings or buildings in "smart growth" locations generate rent and price premiums (see, e.g., Eichholtz et al. 2010, 2013; Pivo and Fisher, 2010, 2011; Fuerst and MacAllister, 2011). Others provide evidence of better investment return associated with sustainable development (see, e.g., Miller, et al., 2008; Pivo and Fisher, 2010; Deng et al. 2012; Deng and Wu, 2014).[1] A natural question that arises is how the financing of real estate is affected by going "green".

Most real estate developments and investments, especially commercial real estate, rely on debt – a mortgage loan collateralized by the property. Do loans on green properties perform better than those on non-green properties? Do borrowers of green properties pay lower interest rates? Are loan terms on green properties different? In this paper, we try to answer these questions by using a novel dataset that matches commercial mortgage and green building information.

Empirically, identifying the effects of "greenness" on property or loan outcomes is challenging due to the well-known endogeneity issue: a property's green status and the performance of a property/loan are subject to common drivers or correlates, and unfortunately some of those drivers or correlates are unobservable or difficult to control in regressions. For example, many of the green buildings are prime real estate in superior urban locations, which can support green innovations. Being in those locations definitely helps property and loan performance. Therefore, unsuccessful control of the location factor would lead to endogeneity. To address this issue, we collect data and exploit both the cross sectional and time series variations in Energy Star labels and LEED certification of CMBS properties to help our identification. As we will show later, over 80 percent of green office properties were not green at loan origination, and they receive an Energy Star label and/or LEED certificate later during the life of the loan. Therefore, we

[1] Devine and Chang (2015) also finds better retail business income associated with "green building".

compare the risk of the same loans before and after they become green in order alleviate the problem of unobservable loan and property characteristics, which helps us identify the green effect. Meanwhile, the cross sectional variation among different properties in their green status as well as the various timing of their appearance in our sample help us identify effects associated with time and observable loan/property characteristics.

In our following analysis of loan terms, the cross sectional and time series variations in the timing of becoming green help us again. Obviously, becoming green five years after loan origination would not have an impact on the original loan terms, as those terms would have been set before the existence of the green status. Therefore, in loan term regressions, we not only compare loans for green and non-green properties, we also compare properties that are green at and after loan origination. While the effect that is associated with green status achieved after loan origination could be due to unobservable differences between green and non-green properties, additional effect, if any, associated with green status at loan origination should reflect the benefits of being green.

Our main data comes from Trepp and the US Green Building Council (USGBC). All properties in our sample were geocoded so the Trepp and USGBC datasets could be merged based on the longitude and latitude of each property. Among the four major commercial property types in our data, the office sector had the highest number and percentage of green buildings, while the multifamily and industrial sectors had very few. Therefore, our analysis mainly focuses on office CMBS loans even though we try to generalize our analysis to the retail sector. Our office CMBS loan sample contains over 6,000 loans.

An initial comparison shows that the default rate of non-Energy Star properties is about 17% while that of Energy Star properties is less than 10%. The default rate difference between LEED certified and non-LEED certified properties is even bigger: 16% for non-LEED certified properties and 6% for LEED certified properties. Those properties with both Energy Star label and LEED certificate have the lowest default rate of 4.8%. Even after controlling for differences in loan and property characteristics, green properties show a 40~60% lower default rate.

Our identification comes from the hazard model based on longitudinal data. For each loan, we construct quarterly observations (event-history) from loan origination to loan termination or the

date of our data collection, whichever comes first. In the event-history data, we have the current green status of the loan, current loan-to-value ratio (LTV), current debt-service coverage ratio, occupancy rate, macroeconomic and property market information, together with all the static loan and property characteristics. Model results show that being green (either Energy Star labeled or LEED certified) could lead to more than 30% reduction in loan default risk, *ceteris paribus*.

To further alleviate concerns of uncontrolled locational differences, we conduct a matched-sample analysis. For each green office property, we find nearby properties that are comparable in size, age, value per square foot and local accessibility as measured by Walk Score. Based on a sample of 395 green properties matched to 609 non-green properties, we re-run the hazard models and find the green effect again to be statistically and economically significant.

We also conduct analysis to try to understand the mechanism of the "green effect". We find that being green is significantly associated with increased debt-service coverage ratio. Therefore, we cannot rule out the possibility that the "green effect" is fully or partially due to the higher order effect of DSCR in our model. This would be consistent with prior work which shows that green properties can have higher net operating incomes due to higher rents, lower operating costs or lower vacancy rates (Eichholtz et al. 2010, 2013; Pivo and Fisher, 2010, 2011; Fuerst and MacAllister, 2011).

We further exploit the richness of our data to show that higher degrees of greenness actually contribute more to the green effect on mortgages. In our data, we not only have indicators of property green status and timing, we observe the number of green points received by the property owner for all the green properties. Research shows that those points are correlated with energy efficiency, which can affect net operating income thru operating expense, and there are variations across green properties. If the green effect is solely due to the "label", the number of green points should not matter. In contrast, what we find is significant variation in default risk with respect to green points after controlling for all other factors. This result helps us reject the hypothesis that the green effect is purely due to the green "label".

In terms of loan terms, we find that in the matched-sample, green status at loan origination is associated with an 8 bps interest rate reduction while green certification after loan origination has

no significant effect. Therefore, we conclude that green property owners were able to get lower cost of debt. In addition, we find that being green is associated with significantly longer interest-only (IO) periods, which is an important benefit to commercial mortgage borrowers. Being green is also associated with shorter loan amortization terms, which could be due to enhanced income potential for borrowers on green buildings and thus higher debt service ability.

Interestingly, we find our results cannot be generalized to retail CMBS loans. As we will discuss more in detail later, this could be due to our data limitations as there are only a handful of green properties in the retail sector. Or it could be that being green in the retail sector is not as significant a benefit as in the office sector.

Our empirical analysis and findings contribute to the sustainable development literature in several important ways. First, it adds to the growing literature on the economics of sustainable development. In recent years, researchers have accumulated important understanding of how green development affects property price and investment/development return. However, we have very limited knowledge about its impact on debt performance, especially in the commercial sector. Kaza et al. (2014), Rauterkus et al. (2010) and Riley and Tian (2015) present some evidence that default risk is lower in Energy Star labeled homes or homes with better location efficiency. Pivo (2013, 2014) provides preliminary evidence about a smart location effect in Fannie Mae multifamily loans. The current paper fills that gap and covers a very important sector of the commercial market, the office market.

Second, the current paper answers a particularly important question about loan pricing, which is whether debt collateralized by sustainable real estate enjoys lower cost. Eichholtz et al. (2015) is the only study we find in the literature that examines this issue. It suggests that environmentally-certified commercial real estate held by REITs are financed at lower spreads. But the authors are not able to track the performance of those loans in the same study. In contrast, we answer both the cost of debt and loan performance questions using a unified sample of commercial mortgages. The match between *ex ante* loan pricing and *ex post* loan performance helps us better understand why there is a pricing effect.

Third, from a methodological perspective, we develop methods to deal with potential endogeneity issues. A critical shortcoming of many of the existing studies on green buildings is

the lack of control of unobservable factors, especially unobservable locational factors. Our hazard model with time-varying green variables and our matched-sample analysis greatly alleviate that concern.

At a practical level, the current paper provides important implications to the business community. From an urban development perspective, evidence presented in this paper should be used to promote green building designs as they not only have environmental merit but also are economically beneficial. Sustainable developers and investors should argue for more liberal terms on mortgage loans for sustainable development given the superior performance of those loans. On the other hand, lenders and investors should be encouraged to offer such liberal terms.[2] From an investment perspective, results in this paper could support the creation of new CMBS products that target green labelled properties.[3] Finally, from a risk modeling perspective, results from this paper can help investors improve their ability to predict default risk when they include green building information in their models.

The rest of the paper is organized as follows: in the next section, we describe our data assembly effort; section 3 explains our analysis and results on the relation between green development and loan performance; in section 4, we present regression results on interest rate and other loan terms; our conclusions and discussions are in a final section.

2. Data

2.1. CMBS loan data

Our CMBS loan data is from Trepp. Trepp partners with the Commercial Real Estate (CRE) Finance Council to gather detailed CMBS loan information from monthly master servicers' reports. The format of the report is laid out in the CRE Finance Council's Investor Reporter Package (IRP) and provides an internally consistent set of data across all CMBS loans. The raw data we received from Trepp include over 10 million monthly observations of loan performance information, including the status of the loan such as prepaid, delinquent, foreclosed or current in

[2] Related to this, Fannie Mae announced on February 6, 2015 a reduction in mortgage interest rate for green-certified multifamily properties.
[3] The CMBS community has indicated strong interests of the creation of "green Mortgage-backed Securities."

each month, and updated loan balance, DSCR, occupancy rate and loss information if the servicer reports such information[4].

The over 10 million loan performance records in our database are for nearly 90,000 CMBS loans from 658 CMBS deals. All the loans in our dataset are for single properties so each loan can be tied to a specific location for analysis of locational features.[5]

We have specific information for each loan such as origination date, original balance, actual rate (mortgage note rate adjusted by points), maturity term, amortization period, interest-only periods, property type, property rentable area, property year built, location of underlying property (address, longitude and latitude), prepayment provisions, originator, servicers (both master and special servicers), the date the loan was securitized (deal cutoff date), face value at the time of securitization, and LTV, net operating income, and DSCR at securitization. For a small portion of the loans that are adjustable-rate mortgages, we know the rate index, margin, cap, etc. The dataset is comparable to that used in An et al. (2013).

We focus on fixed-rate mortgage loans and exclude ARMs, which are less than 2 percent of the sample. Given that we have to use the Real Capital Analytics (RCA) by-MSA and by-property type commercial real estate price index to calculate contemporaneous LTV, and that the RCA index is available for only a limited number of metropolitan statistical areas (MSAs), we focus on CMBS loans from the RCA-covered MSAs. Those MSAs are actually the top MSAs in terms of CMBS loan origination. We also exclude loans originated before the year of 2000 because the RCA price index only starts from 2000. Further, we verify loan information on rate, LTV, and original balance at origination and exclude a few loans with invalid information on those variables. A representativeness check shows that the remaining loan sample is representative of the original CMBS loan sample.

In terms of collateral property type, the four major types are office, retail, multifamily and industrial. As we will discuss later, the office sector has the highest number and percentage of

[4] The IRP requires borrowers to provide regular updates of the current NOI, occupancy rate, and DSCR for each property. In some cases servicers have been unwilling to enforce such a rule, resulting in some missing values in updated occupancy rates and DSCR in our data.
[5] Trepp also has data on a small amount of loans for multiple properties that we did not study.

green buildings in our data set while there are only a handful of green properties in the multifamily and industrial sectors. Therefore, our main analysis focuses on office loans.

2.2. Green building information and location information

Well-accepted green building measures include the Energy Star label issued by the US Environmental Protection Agency (EPA) and the Leadership in Energy and Environmental Design (LEED) certification issued by the US Green Building Council (USGBC).

To be Energy Star labeled, a building must be in the top quartile of energy efficiency when compared to other properties with similar operational characteristics (i.e. size, weather conditions, number of occupants, number of computers, and hours of operation per week). The LEED program has different certification levels including "Certified", "Silver", "Gold", and "Platinum", and labeling standards are substantially more complex than those required for an Energy Star label. Additional points in the certification process are awarded for such factors as "site selection," "brownfield redevelopment," and the availability of "bicycle storage and changing rooms," as well as energy performance (Eichholtz et al. 2010).

In our study, both the Energy Star label and LEED certification information were provided by USGBC. USGBC used the property features, address, and geocodes (latitudes and longitudes) found in both the USGBC and the Trepp loan datasets to determine whether properties in our loan data matched properties in the USGBC green buildings database, and if so whether the matching properties were LEED-certified or Energy Star labeled and the date that status was achieved.[6] The timing of green status achievement for each property is particularly important for our study, as we will discuss later. In addition, USGBC provided the Energy Star or/and LEED score of each green property. Those scores were the points received by each property when they achieved green status and they measure variations in energy efficiency and/or greenness across green properties. Therefore, the green scores contain more information than just the green label, but they are generally not public knowledge. In fact, it is not likely tenants would pay as much attention to those scores as they do to the green label.

[6] USGBC matched the Trepp data to both their public records available thru their Green Building Information Gateway and confidential records that identify LEED properties that are not publicly disclosed.

As location plays such an important role in real estate, we further collect detailed location information on each loan based on geocoding of the properties. Among the various location metrics, we pay special attention to walkability, which is akin to local accessibility. Walkability has been linked to various social and environmental benefits and increases with the number of desired destinations within walking distance of a property (Pivo and Fisher, 2011; Federal Highway Administration, 2012). We use the Walk Score variable provided by Redfin to measure walkability. Walk Score rates the walkability of an address on a 100 point scale by determining the distance to educational, retail, food, recreational and entertainment destinations. Studies show it to be a reliable and valid estimator of neighborhood features linked to walking (Carr et al. 2010 and 2011; Duncan et al. 2011; Duncan et al. 2013).

2.3. Our sample

Only about 1 percent of our properties are LEED certified. Energy Star properties are more prevalent than LEED properties; however it still only comprises a small subset (about 3 percent) of the sample. When we break down our loan sample by property type, we find that office properties have the highest percentage of Energy Star labeling and LEED certification, at about 11 percent and 4 percent, respectively. Among retail properties, less than 1 percent are green labelled. The multifamily and industrial sectors have even fewer green properties. Therefore, we focus on office properties in our main analysis, but we try to generalize our analysis to retail properties later. Multifamily or industrial properties are excluded from our analysis.

Our final office CMBS loan sample contains 6,304 fixed-rate mortgage loans. These loans were originated between 2000 and 2012, among which the year of 2006 sees the highest number of originations (1,265). Post-crisis, there were only a handful of loans originated in 2008, and 2009 saw no new origination. An increasing number of loans were originated since 2010. The collateral properties are located in 17 US MSAs including New York, Los Angeles, Chicago, etc. These MSAs are the largest office markets.

Among the 6,304 office properties, 673 properties were ever Energy Star labelled and 252 were ever LEED certified. By “were ever” we mean they were labelled or certified during some or all of the time their loan was in our dataset. There are overlaps between Energy Star label and LEED certification – 156 properties have both. As noted, not all green properties achieved their

green status at loan origination. In fact, only 113 loans were Energy Star labelled and 10 were LEED certified at loan origination. The rest of the green properties achieved their green status at various later stage during the life of the loan.

The average original loan balance is $24 million and the average original LTV is 68%. The average original debt-service coverage ratio is 1.82 and the average occupancy rate at loan origination is 95%. The average loan term is 114 months (9.5 years) and the most popular loan term is the 10-year. These loans amortize at a much slower pace than they mature: the average amortization term is 316 months (26 years) and a majority have a 30-year amortization term. Therefore, many of these loans have balloon payments. A significant portion of these loans have interest-only (IO) terms. In terms of interest rate, there are large variations: the average is 6% but it ranges from 4.7% to 15%. Table 1 contains statistics of additional variables for the office loans such as age, rental area, value per square foot, Walk Score, etc.

3. Sustainable Development and Loan Default

3.1. Why does sustainable development matter?

Sustainability features could reduce mortgage default risk by increasing net operating income (NOI) and/or property value. NOI is related to the debt service coverage ratio (DSCR) and property value is related to the loan to value ratio (LTV), both of which are known default risk determinants (Vandell, 1984, 1992; Titman and Torous, 1989; Kau et al. 1990; Vandell et al. 1993; Goldberg and Capone, 1998, 2002; Archer et al. 2002). In a default risk model, if the positive sustainability effects on NOI and value are not already reflected in the LTV or DSCR variables, because the sustainability effects were not fully accounted for in the income or value estimates used to compute LTV or DSCR, then we should see that sustainability has a separate effect on default risk independent of LTV or DSCR.

This of course raises the question of why NOI and value might be higher in green buildings. NOI could be higher if there is greater demand for green features by prospective tenants that drives up rents or occupancy. That could occur if tenants think green buildings will improve their productivity, competitiveness, or status. NOI could also be higher in sustainable buildings if their

green features lower operating expenses. That could occur if they use less energy or water, which they are designed for, or if they lower tenant turnover because of greater tenant satisfaction.

If higher NOI is the result of greater tenant demand, then it could simply be that green designations or labels on buildings are enough to produce the sustainability benefits to default risk if the designations or labels are enough to cause tenants to think a building will deliver the expected tenant benefits. In that case, all green labeled buildings should see the same reduction in default risk. If on the other hand, higher NOI comes from lower operating expense, then the greener a building is (i.e., the more green points it earns in a green rating program), the higher its NOI should be and the lower its default risk. Our analysis will test whether lower default risk in green buildings comes from the green label alone or whether risk is further reduced as green achievement improves.

As to why value might be higher in sustainable properties, we would see higher value if higher NOI translates into higher value, which is normally expected. But higher value could also occur if there is more demand for green buildings among buyers that is reflected in lower cap rates. That might happen if buyers think green properties carry lower risk, or will be more attractive to future buyers or tenants, or may outperform in a future with carbon pricing or water shortages. Here again, however, it is possible that green labeling alone is all that buyers use to bid up the price for green properties. But as before, our analysis will test whether the green label alone or higher green achievement are linked to lower default risk.

Another reason why sustainability may affect default risk, which we cannot directly test with our dataset, is that green features, NOI and value may co-vary with borrower characteristics. We would note, however, that some borrower characteristics have been insignificant default predictors in other studies. Vandell et al. (1993) used borrower type (individual, partnership, corporation, other) in their analysis of commercial mortgage defaults, as did Ciochetti et al. (2003), and neither study found them to be significant. Archer et al. (2002) found that property size and value, which could be related to management skill, were unrelated to default in multifamily properties. It is also possible that lenders would have adjusted original loan terms based partly on their assessment of borrower characteristics, such as management skill. Therefore, the original and contemporaneous loan to value and debt-service coverage ratios, which we use in our study, may be proxies and controls for borrower characteristics.

Nevertheless, there may be something about green building owners that reduces their likelihood of defaulting on green buildings. Perhaps they are better managers or less willing to give up the green buildings in their portfolio which they worked hard to acquire.

3.2. Initial comparison between green and non-green properties

Among the 6,304 office CMBS loans in our sample, 1,001 loans entered into default, which we define as 60-day delinquency. Therefore, the default rate is about 15.9%. However, the default rate of green properties is significantly lower.

Table 2 presents a simple comparison of default rates of green and non-green office properties. Those that are Energy Star labelled have a default rate of 9.4%, in contrast to the 16.7% default rate of non-Energy Star labelled properties. In another word, Energy Star labelled properties have a greater than 40% lower default rate. The difference between LEED certified and non-LEED certified properties is even bigger: only 6% of LEED certified properties entered into default while 16.3% of non-LEED certified properties entered into default. The percentage difference is over 60%. Finally, we see that properties with both the Energy Star label and LEED certificate have the lowest default rate at 4.8%, which is 71% lower than those without both.

Certainly, some of the aforementioned differences could be due to discrepancies in loan and property characteristics between the two groups of loans, green and non-green. For example, green properties on average are more expensive, possibly due to better locations in the city (Table 3). Therefore, to account for differences in loan and property characteristics, we run a simple Logit model where our dependent variable is a default indicator (0 or 1) and our covariates include green indicators and log loan balance, origination LTV, occupancy rate, amortization term, maturity term, property value per square foot, age of the property, as well as MSA- and vintage-dummies. Note that the property value (per square foot) variable should serve as a strong control of many factors such as location quality and building amenities.

In Table 4, we present our Logit model results. We see that after controlling for loan and property characteristics, Energy Star labeled properties still have a 38% lower default rate than properties without Energy Star label and that LEED certified properties have a 57% lower default rate than non-LEED certified properties. Those with both Energy Star label and LEED certificate have the lowest adjusted default rate (67% lower than those without any green label).

3.3. Hazard model of default probability

The Logit model helps tease out the default rate differences between green and non-green properties that are due to observable variations in loan and property characteristics. However, one might still be concerned about unobservable differences between green and non-green properties that contribute to both loan default risk and the likelihood that the property would achieve green status. If such unobservable common factors exist, it will lead to endogeneity. In that regard, we exploit both the cross sectional and time series variations in property green status as well as the timing of becoming green, and estimate hazard models to help identification.

The idea is that since many green properties hadn't achieved green status at loan origination we can compare the default risk of the same loan before and after it becomes green. Such a comparison would greatly eliminate the impact of unobservable loan and property characteristics, and thus would help us identify the green effect. Meanwhile, the cross sectional variation among different properties in their green status as well as the various timing of their appearance in our sample would help us identify effects associated with time and observable loan/property characteristics.

The default probability model we estimate is a standard Cox proportional hazard model, which is widely used in the mortgage literature (see, e.g. Vandell, 1993; Seslen and Wheaton, 2010; An et al., 2013). In a Cox proportional hazard model, the left-hand side (LHS) of the equation is hazard rate, which is the conditional probability of default for a loan at a certain age/period after origination given that there has been no default before that age/period (i.e. the conditional default rate). The hazard rate of default for a particular loan at a certain age/period is modeled as a function of a baseline hazard function, which is a function of the duration (age) of the loan, and a function of covariates, which are the default risk factors.

Assume the hazard rate of default of a mortgage loan at period T since its origination follows the form:

$$h_i\left(T;Z_i\left(t\right)\right)=h_0\left(T\right)\exp\left(Z_i\left(t\right)'\beta\right),i=1,\cdots n \qquad (1)$$

Here $h_0(T)$ is the baseline hazard function, which only depends on the age (duration), T, of the loan and is an arbitrary function that allows for a flexible default pattern over time; $Z(t)$ is a vector of covariates for an individual loan that include all the identifiable time-varying or time-invariant risk factors. The green indicator is one of the covariates and our focus variable. Different from that in the Logit model we estimated earlier, the green indicator in our hazard model is a time-varying dummy variable. It takes a value of zero before a green property achieves the green status during the life of the only.

Our control variables include essentially all those identified by the existing literature as significant drivers of commercial mortgage default probability or their equivalents. These include the contemporaneous LTV and DSCR, original loan balance (in log terms), original LTV (dummy for original LTV higher than 75%), refinance incentive (measured by percentage decline in market prevailing mortgage interest rate relative to the current note rate), age of the property (dummies for new and old properties, which also proxy to some degree for building class; for a discussion see Pivo and Fisher, 2010), prepayment restrictions (i.e. the presence of a prepayment lock out, prepayment penalty and yield maintenance in a particular loan quarter, which tend to limit refinancing and increase default risk), MSA unemployment rate innovation in a particular quarter (i.e. the change in the MSA unemployment rate over the prior 4-quarter moving average, as a business cycle indicator), volatility of the 10-year Treasury rate, volatility of the RCA price index for each of the 17 MSAs and property types over the prior 12 quarters, and MSA- and vintage-dummies. For details on these control variables, please see An et al. (2013) and An et al. (2016). In addition, we include per square foot value of the property as an additional control variable and it should capture most of the location and property amenity related factors.

To construct contemporaneous LTV, we utilize the RCA price index (by property type and by MSA) to bring property value up-to-date, and calculate contemporaneous LTV as the ratio between current property value and remaining loan balance that is in the Trepp data. For contemporaneous DSCR and occupancy, if there is a quarter that the servicer did not report the current DSCR or occupancy rate we use the nearest quarter's value either before or after the missing quarter, as a proxy.

In Table 5, we report sample statistics of our time-varying covariates including contemporaneous LTV, DSCR and the green indicators. Each observation represents a loan record for a specific quarter. Particularly we compare the statistics of the defaulted and non-default loans both at loan origination and at loan termination. For example, we see that the average LTV at loan origination of defaulted loans is only about 10 percent higher than that of non-defaulted loans (70% vs. 64%), while at loan termination defaulted loans have an average contemporaneous LTV almost 60 percent higher than that of non-defaulted loans (93% vs. 59%). Without surprise, contemporaneous LTV is later found to be an important driver of default. The green variables demonstrate very similar patterns. For example, the same portion of properties (2%) have Energy Star label at loan origination among defaulted and non-defaulted loans, however, at loan termination 10% of non-defaulted loans have Energy Star label but only 4% of defaulted loans have Energy Star label. This simple bivariate analysis suggests that the green status of a property is associated with lower default risk.

3.4. Hazard model results

Our main hazard model results are in Table 6. We only present results of our focus variables in the table and refer readers to Appendix Table 1 for the full model results. The statistics given are the regression coefficient and significance, and the hazard ratio (in parenthesis). The hazard ratio is the predicted change in the risk of default produced by a one-unit change in the parameter while other variables are held constant. A hazard ratio greater than 1 indicates that the default risk increases when the variable increases and a hazard ratio less than 1 indicates that risk decreases when the variable increases. For the binary covariates the hazard ratio estimates the ratio of the risk of default in the loans with the feature to the default risk in the loans without the feature. For the continuous covariates, because they are standardized, the hazard ratio estimates the change in risk associated with a change of one standard deviation in the variable[7].

We have two model specifications: in model 1, Energy Star label is the green indicator and our focus variable; in model 2, our focus variable takes a value of 1 if the property is Energy Star labelled or LEED certified (green in general). We do not separately use a LEED certification indicator as only a very small portion of the properties are LEED certified (especially with the

[7] Note that in our model estimation, all continuous variables are standardized to zero mean and unit variance.

event-history sample the percentage is extremely low). Remember our focus variable is time-varying – for the same loan the green indicator is zero before the property achieves green status and one after.

In the full model results, we see that Energy Star label has a negative impact on default hazard rate and the impact is statistically significant (model 1). From the hazard ratio, we see that the impact is also economically significant as having the Energy Star label reduces the hazard rate by 33% (1-0.670 = 0.33), *ceteris paribus*. In model 2, the result is very similar: being Energy Star labelled or LEED certified reduces hazard rate by 32% (1-0.676=0.324), all else equal.

From Appendix Table 1, we can see our control variable results are highly consistent with those in the existing literature. For example, contemporaneous LTV is highly significant and positively related to default probability – the higher the current LTV, the more likely the loan will enter into default. Contemporaneous DSCR is also significant and negatively related to default probability – the higher the DSCR, the lower the chance is that the loan will be defaulted. MSA unemployment rate innovation is positive and significant. This means when the local economy is bad, the chance of these CMBS loans being in default is higher. The high LTV (at origination) loans and loans of larger size have higher probability of default, all else equal. When there is lock out, refinance incentive is significant and positively related to default probability, which is consistent with findings in the existing literature (see, e.g., An 2009; An et al., 2013). Value per square foot is negative and significant, meaning that properties in better locations or of better quality are less likely to default.

3.5. Matched-sample results

In addition to utilizing the longitudinal data and hazard model to help identification, we also conduct a matched-sample analysis. For each green office property, we first find office properties in the same zip code that are comparable in size, age, value per square foot and local accessibility measured by Walk Score. For example, for value per square foot and Walk Score, we only allow ±10% discrepancy for a match. For age, we allow 10 years difference. For size measured by rentable area, we allow 50 percent difference. After the match, we then rank order the matches based on the Euclidian distance between the subject property and the match. Distance is calculated based on the longitude and latitude of the two properties. Finally, for green

properties with multiple non-green property matches, we select the two closest matches. As not all green properties have matches, our final matched-sample contains 395 green properties matched to 609 non-green properties.

Our matching algorithm greatly mimics tenants' and investors' searching for substitutes in the real estate market, therefore, the matched-sample should greatly alleviate concerns of unobservable locational differences.

With the matched sample, we re-run the hazard models[8]. Main results are again in Table 6. Here we see that the focus variable results are even stronger than those from the full sample. Properties with Energy Star label show significantly lower default risk than those without Energy Star label, *ceteris paribus*. The difference is 51%. The model 2 result shows that being green (either Energy Star labelled or LEED certified) can reduce default risk by 49%.

3.6. The mechanism

Our analysis so far provides strong evidence that being green can reduce default risk of office CMBS loans. But we want to understand why.

Being green, whether LEED certified or Energy Star labeled, is associated with enhanced on-site energy efficiency (Newsham et al. 2009; Scofield 2013), and the existing literature has found a positive impact of green development on occupancy and rent. LEED certification also promotes water efficiency, which can reduce operating costs, and public transportation access, which is linked to higher market value and rents (see reviews by Cervero et al. 2002 and Pivo and Fisher 2010). Therefore, from an operational perspective, being green is likely to be associated with enhanced net operating income (NOI) because of increased revenue and reduced operating expenses. Indeed, Pivo and Fisher (2010) found higher NOI per square foot for investment grade Energy Star office properties due to rent premiums (as did Eichholtz et al. 2010, Fuerst and McAllister, 2011, and Wiley et al, 2008) and lower utility expenses per square foot. For commercial mortgage loans, NOI is what is used to service the loan. Therefore, there could be an NOI (cash flow) channel through which green development helps reduce default risk.

[8] Number of matches is used as weight for the subject (green) properties.

On the other hand, reduced default risk could be due to the green label itself. For example, a green property owner might not be willing to give up his or her property by going into default because of the sunk cost incurred by him or her to obtain the green label. It could even be that the owner would develop emotional attachment to the property due to the green status of the property.

Recall that in our hazard model, we do have contemporaneous DSCR as a control variable. So, one could interpret the green effect as additional effect that is beyond the cash flow (NOI) effect. A caveat here is that this interpretation is based on the assumption that the green variable and the DSCR variable are orthogonal. Otherwise, the green variable could pick up the higher-order effect of DSCR, or vice versa. Therefore, we first test the correlation between the green variables and DSCR. Result shows that the correlation between having Energy Star label and contemporaneous DSCR is indeed significant and the correlation coefficient is about 8% (Table 7). The correlation coefficient between being green and contemporaneous DSCR is also about 8%. Judged by these statistics, the magnitude of the correlation is not high enough to lead to multicollinearity concerns. However, we cannot reject the hypothesis that the green impact is through the NOI channel given that the correlation is significant.

Next, we devise another test to help understand the mechanism. In our green building data, we not only observe green label and the date when the label is obtained but also green points received by each property during its certification process. As we discussed earlier, these green points indicate the relative energy efficiency of different green buildings[9]. If the green effect purely arises from the green label itself, we should not observe differences in default risk among green properties with different green points. Therefore, we re-run our Logit model and hazard model with green points as the focus variable with only the green properties. Given that the green scores for Energy Star label and LEED certificate are on different scales, we rescale those two scores and standardize those two scores.

[9] For Energy Star, higher points are a directly related to energy performance. For LEED, higher points can also reflect other green achievements, however Scofield (2013) shows a correlation between higher LEED rating levels (i.e. moving from certified to silver, gold and platinum), which comes from earning more points, and greater on-site energy efficiency. This is not surprising because the percentage of all points that can be earned toward LEED certification from energy related features has been about one-third since 2009 and was about one-quarter before.

In Table 8, we present our main results of this test. We can see that in both the Logit model and the hazard model, the green points variable is significant and negative, meaning that higher green score is associated with reduced default risk. Such results help us reject the hypothesis that the green effect is purely due to the green label itself, and point to the NOI channel also being operational.

3.7. Retail CMBS loan results

Finally, we extend our analysis to retail CMBS loans, and find that we cannot generalize our results to retail loans. For example, in Table 9 we show that green variables in the hazard model are not significant for retail loans. The insignificance could be due to our data limitations: there are only a handful of green properties in the retail sector (61 out of 8,747 properties are green), therefore, insufficient variation in the data may prevent us from identifying a significant green effect.

Another possible reason is that being green in the retail sector is not as significant a benefit as in the office sector. The US Department of Energy 2012 Commercial Building Energy Consumption Survey shows that energy intensity in offices can be higher than for retail, especially for heating and cooling. Also, it's possible that tenants care more about whether their office building is green than whether their retail building is green. Green buildings may have more competitive advantage when it comes to office work by way of more healthy, light, comfortable, and productive space (Feige et al. 2013) and those things may be less of a concern for retail productivity because they don't affect shoppers as much.

4. Sustainable Development and Mortgage Terms

4.1. Mortgage interest rate

In a competitive lending market, the interest rate paid by the borrower and that charged by the lender should reflect the risk of the loan. Given that we see sustainability is associated with reduced mortgage default risk, we are interested in whether mortgage loans of sustainable development carry lower interest rate.

The CMBS loans we analyze were originated during different time with different maturity terms. Therefore, to make the interest rate comparison meaningful, we focus on loans with the most popular maturity term, 10-year maturity, and calculate the mortgage spread of each loan. The comparison will then be on the mortgage spread. Mortgage spread is defined as the mortgage interest rate minus comparable maturity Treasury rate (risk-free rate). Due to prepayments and defaults, the actual life of 10-year CMBS loans is usually smaller than 10 years. Therefore, we use the 7-year Treasury bond rate as the benchmark.[10]

Mortgage spread is potentially affected by various loan characteristics beyond the green status of the property. Therefore, we conduct a regression analysis to test the impact of sustainability.

The regression takes the following form:

$$r_i = \gamma S_i + \beta X_{i,t} + \varepsilon_i, \; i = 1, \dots N; t = 1, \dots T, \qquad (2)$$

where r_i indicates the mortgage spread of loan i originated at time t, S_i denotes the vector of our sustainability measures, $X_{i,t}$ are control variables including loan characteristics and market conditions, and ε_i is the disturbance term.

The control variables include the ones we see in the Logit model: original loan balance (in log terms), original LTV (dummy for original LTV higher than 75%), LTV and occupancy rate at loan origination, amortization term, IO periods, whether there are prepayment restrictions such as lock out, prepayment penalty and yield maintenance, the age of the property (dummies for old and new), the per square foot property value, yield slope curve, corporate credit spread, volatility of the 10-year Treasury rate at loan origination, and MSA- and vintage-dummies.

Note that in our data we can classify green properties into two groups: one group are those properties already being green at loan origination, and the other group are those properties that had not become green at loan origination but achieved green status after loan origination. Becoming green five years after loan origination would not have an impact on the original interest rate as the rate was set before the existence of the green status. Therefore, in mortgage spread regressions, we not only compare loans for green and non-green properties, we also

[10] Alternatively, we use interest rate swap rate as the risk-free rate benchmark. Results are robust.

compare properties that are green at and after loan origination. The effect that is associated with green status achieved upon loan origination could be due to unobservable differences between green and non-green properties, but additional effect, if any, associated with green status after loan origination should reflect the benefit of being green.

We report our main regression results in Table 10 and refer readers to the complete results in Appendix Table 2. Interestingly, we see that in the full sample loans with green status achieved after loan origination have significantly lower interest rates than those that have never been green. As we mentioned earlier, a possible explanation is that this variable captures some unobservable differences between green and non-green properties. Importantly, we see that loans with green status at loan origination have significantly lower interest rates than non-green properties and the difference is bigger than that between loans becoming green after loan origination and loans never being green (-11 bps vs. -7 bps).

On the matched-sample results, we see that there is no significant difference between properties that achieved green status after loan origination and those that are never green, although the sign is in the expected direction. But the difference between properties that were green at loan origination and non-green properties remain significant. Since we know our matching algorithm alleviates concerns of unobservable variables, we believe these results confirm our conjecture that, on the one hand, there are unobserved differences between green and non-green properties, and on the other hand, being green at loan origination is associated with lower mortgage interest rate.

Coefficients of the control variables shown in Appendix Table 2 largely conform to our expectations and findings in the existing literature. For example, LTV at loan origination, amortization term, being an old property, yield slope, credit spread and Treasury rate volatility are all positively associated with mortgage spread. Origination LTV higher than 75 percent is negatively associated with mortgage spread, possibly due to selection effect – lenders are willing to both accept a high LTV and offer a low interest rate on some really good projects. This is consistent with findings in the existing literature (see, e.g., An et al, 2013). The positive relation between lock out and prepayment penalty clauses could be due to similar reasons – lenders require those clauses and at the same time charge higher interest rate on some risky projects. There are also significant vintage- and MSA-fixed effects.

4.2. Other loan terms

In addition to interest rate, we examine other loan terms and test whether green properties have different loan outcomes than those of non-green properties. The regressions are similar to that in equation (2), and key dependent variables include loan-to-value ratio (LTV), interest-only (IO) term and amortization term.

Again we focus on loans with 10-year maturity term. Regression results of our focus variables are in Table 11. Interestingly, we see that green properties have significantly longer IO periods, especially those that are green at loan origination. This effect is after controlling for all other loan and property characteristics such as log loan balance, LTV, occupancy rate, amortization term, prepayment restrictions, value and age of the property, macroeconomic environment as well as MSA- and vintage-fixed effects. To the extent that IO terms are good for borrowers, green properties enjoy this benefit.

In terms of amortization term, the results are opposite – green properties have significantly shorter amortization terms. This might be due to stronger income earnings of green properties and thus borrower's higher debt service capacity.

Finally, LTV results show that green properties have significantly smaller loan size given the value of the property. But there is almost no difference between properties that were green at loan origination and properties that achieved green status after loan origination. These results are a little surprising as one would expect that lenders would be willing to lend more to green property owners, *ceteris paribus*. It may reflect a lack of information available to lenders about the financial benefits of being green or other constraints on their lending practices.

5. Discussion and Conclusion

An increasing number of studies show the economic benefits of sustainable development. However, evidence on the debt side of real estate development is still quite limited. This paper begins filling the gap by providing the first systematic analysis of the relation between green development and debt financing for a major commercial real property type, office.

We have demonstrated that green office buildings are associated with a significant decline in default risk in CMBS loans. Our comparison of default rates of green and non-green properties

shows that Energy Star and LEED properties have a 40% and 60% lower default rate, respectively. The rates were nearly as high in a simple Logit model controlling for loan and property characteristics. We then controlled for potentially unobserved differences between green and non-green properties by using longitudinal data to observe the effect on risk before and after individual properties became green in a hazard model where the green indicator is a time-varying dummy variable, where for each loan the green indicator is zero before the property achieves green status and one after. Here we find that being Energy Star reduce default risk by 33% and being either Energy Star or LEED reduces the hazard rate by 32%. Finally we conducted a matched-sample analysis where the benchmark for each green property are comparable properties in the same zip code. Using the matched-sample in the hazard models we find consistent "green" benefits. All of these analyses support our general conclusion that loans on green properties do indeed perform better than those on non-green properties.

As for the possible mechanisms, we tested whether the lower default risk can be explained by its effect on cash flow rather than by the labelling itself by using LEED and Energy Star scores in the Logit and hazard models. Both models support the hypothesis by showing that higher points do reduce default risk. This would not be the case if the effect was caused merely by labelling because higher points are associated with greater energy efficiency, water efficiency and other benefits which are likely to reduce operating expense (or possibly higher rents and occupancy) and therefore higher cash flow.

Finally, we tested to see if borrowers on green properties enjoy better terms that could be expected from the lower risk. Using a regression to control other factors we find that being green at loan origination is associated with low mortgage interest rate.

Of course, as with any first study of its kind, this project leaves room for more research. As noted, the exact mechanism through which sustainability affects mortgage default is an important topic for future study. There are also other important sustainability features, beyond energy star labelling or green certification that should also be examined, such as walkability, mixed use, and transit-oriented development. It would also be interesting to look at these relationships in other types of loan pools, such as loans held by lending institutions that are not sold into the CMBS market, such as bank loans and life insurance company loans.

Finally, our findings raise the question of whether underwriting tools and practices should be amended in order to take advantage of these results and whether lenders could and should offer more attractive terms to properties with certain sustainability features. Better terms on sustainable properties could improve overall market efficiency and environmental outcomes without exposing lenders to greater risk.

References

An, X. Macroeconomic Growth, Real Estate Market Conditions, and the Time Series Dynamics of CMBS Loan Default Risk, SSRN working paper, 2009.

An, X., Y. Deng and S. Gabriel. Default Option Exercise over the Financial Crisis and Beyond, SSRN working paper, 2016.

An, X., Y. Deng, J. B. Nichols, and A.B. Sanders. Local Traits and Securitized Commercial Mortgage Default, *Journal of Real Estate Finance and Economics*, 2013, 47:4, 787-813.

Archer, W.R., P.J. Elmer, D.M. Harrison, and D.C. Ling, Determinants of Multifamily Mortgage Default, *Real Estate Economics*, 2002, 30:3, 445–73.

Carr, L.J., S.I. Dunsiger, and B.H. Marcus,Walk Score As a Global Estimate of Neighborhood Walkability, *American Journal of Preventative Medicine*, 2010, 39:5, 460–63.

Cervero, R., & M. Duncan, Which reduces vehicle travel more: Jobs-housing balance or retail-housing mixing? *Journal of the American Planning Association,* 2006, 72, 475–490.

Cervero, R., C Ferrell, and S. Murphy, Transit-Oriented Development in the United States: A Literature Review, Transit Cooperative Research Program, *Research Results Digest*, 2002, 52.

Ciochetti, B.A., Y. Deng, B. Gao, and R. Yao, The Termination of Commercial Mortgage Contracts through Prepayment and Default: A Proportional Hazard Approach with Competing Risks, *Real Estate Economics*, 2002, 30:4, 595–633.

Deng, Y., J. M. Quigley and R. Van Order. Mortgage Terminations, Heterogeneity and the Exercise of Mortgage Options, *Econometrica,* 2000, 68(2): 275-307.

Deng, Y., Z. Li and J. Quigley, Economic Returns to Energy-Efficient Investments in the Housing Market: from Singapore. *Regional Science and Urban Economics,* 2012, 42(3): 506-515.

Deng, Y. and J. Wu. Economic Returns to Residential Green Building Investment: The Developers' Perspective. *Regional Science and Urban Economics,* 2014, 47: 35-44.

Devine, A. and Q. Chang. Does a Green-Certified Storefront Mean More Income? Estimating Financial Benefits of Certification for Space Users. AREUEA 2015 National Conference paper.

Duncan, D.T., J. Aldstadt, J. Whalen, S.J. Melly, and S.L. Gortmaker. Validation of Walk Score for Estimating Neighborhood Walkability: An Analysis of Four U.S. Metropolitan Areas, *International Journal of Environmental Research and Public Health*, 2011, 8, 4160–79.

Duncan, D.T., J. Aldstadt, J. Whalen, and S.J. Melly. Validation of Walk Scores and Transit Scores for Estimating Neighborhood Walkability and Transit Availability: A Small-area Analysis, *GeoJournal*, 2013, 78:407–416.

Eichholtz, P., N. Kok and J. Quigley, Doing Well by Doing Good: Green Office Buildings, *American Economic Review*, 2010, 100(6): 2494–2511.

Eichholtz, P., N. Kok and J. Quigley, The Economics of Green Building, *Review of Economic and Statistics*, 2013, 95(1): 50-63.

Eichholtz, P., N. Kok and e. Yonder, Environmental Performance and Cost of Capital: Evidence from REIT bonds and Commercial Mortgages. AREUEA 2015 Annual Conference paper.

Federal Highway Administration, *Health and Environmental Benefits of Walking and Bicycling*, fhwa.dot.gov, 2012.

Feige, A., H. Wallbaum, M. Janser, & L. Windlinger, Impact of sustainable office buildings on occupant's comfort and productivity, *Journal of Corporate Real Estate*, 2013, 15(1), 7-34.

Fuerst, F. and P. McAllister. Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values. *Real Estate Economics*, 2011, 39(1): 45-69.

Goldberg, L. and C.A. Capone, Multifamily Mortgage Credit Risk: Lessons from Recent History. *Cityscape*, 1998, 4:1, 93–113.

——. A Dynamic Double-Trigger Model of Multifamily Mortgage Default, *Real Estate Economics*, 2002, 30:1, 85–113.

Kau, J.B., D.C. Keenan, W.J. Muller III, and J.F. Epperson, Pricing Commercial Mortgages and Their Mortgage-backed Securities, *The Journal of Real Estate Finance and Economics*, 1990, 3:4, 333–56.

Kaza, N., R. Quercia and C. Tian, Home Energy Efficiency and Mortgage Risks, *CityScape*, 2014, 16(1): 279-198.

Korniotis, G.M. and A. Kumar, State-Level Business Cycles and Local Return Predictability, *The Journal of Finance*, 2013, 68(3): 1037-1096.

Miller N., J. Spivey and A. Florance, Does Green Pay Off? *Journal of Real Estate Portfolio Management*, 2008, 12(1): 1-12.

Newsham, G. R., S. Mancini, and B.J. Birt, Do LEED-certified buildings save energy? Yes, but…. *Energy and Buildings*, 2009, 41(8), 897-905.

Pivo, G., The Effect of Sustainability Features on Mortgage Default Prediction and Risk in Multifamily Rental Housing, *Journal of Sustainable Real Estate*, 2013, 5(1): 152-173.

Pivo, G., Walk Score: The Significance of 8 and 80 for Mortgage Default Risk in Multifamily Properties, *Journal of Sustainable Real Estate* 2014, 6(1), 187-210.

Pivo, G. and J.D. Fisher, Income, Value, and Returns in Socially Responsible Office Properties, *Journal of Real Estate Research,* 2010, 32(3): 243-270.

Pivo, G. and J.D. Fisher, The Walkability Premium in Commercial Real Estate Investments, *Real Estate Economics,* 2011, 39(2): 185-219.

Rauterkus, S.Y., G.I. Thrall, and E. Hangen, Location Efficiency and Mortgage Default, *Journal of Sustainable Real Estate*, 2010, 2:1, 117–41.

Riley S. and C. Tian, Location Efficiency & Mortgage Risks for Low-Income Households, AREUEA 2015 National Conference paper.

Scofield J.H., Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emission for large New York City office buildings, *Energy and Buildings*, 2013, 67, 517-524.

Seslen, T. and W. Wheaton, Contemporaneous Loan Stress and Termination Risk in the CMBS Pool: How "Ruthless" is Default? *Real Estate Economics,* 2010, 38(2): 225-255.

Titman, S. and W. Torous, Valuing Commercial Mortgages: An Empirical Investigation of the Contingent-Claims Approach to Pricing Risky Debt, *Journal of Finance*, 1989, 59,165–206.

Vandell, K., W. Barnes, D. Hartzell, D. Kraft, and W. Wendt, Commercial Mortgage Defaults: Proportional Hazards Estimation Using Individual Loan Histories, *Real Estate Economics*, 1993, 4:21, 451–80.

Vandell, K. D., Handing Over the Keys: a Perspective on Mortgage Default Research, *Real Estate Economics,* 1993, 21(3): 211-246.

Wiley, J.A., J.D. Benefield, and K.H. Johnson, Green Design and the Market for Commercial Office Space, *Journal of Real Estate Finance and Economics*, 2008.

Table 1 Summary Statistics of Securitized Office Loans

Variable	Mean	Sum	Std. Dev	Minimum	Median	Maximum
Ever Energy-star labelled	0.11	673	0.31	0	0	1
Ever LEED certified	0.04	252	0.20	0	0	1
Ever energy-star labelled or LEED certified	0.11	718	0.32	0	0	1
Original loan balance ($000s)	24,252	152,886,345	45,204	1000	9,568	806,000
Interest rate (%)	6.00	37796	0.88	4.66	5.81	15.00
Loan-to-value ratio (LTV, %)	67.75	427116	12.22	23.40	71.30	92.33
Debt-service coverage ratio (DSCR)	1.82	3048	0.82	1.17	1.60	3.90
Occupancy rate (%)	94.70	576827	7.00	21.22	97.60	100
Term (months)	114	720221	23	35	120	360
Amortization term (months)	316	1992570	111	35	360	432
Interest-only (IO) periods (months)	32	200745	42	0	1	219
Age of the property	36	220037	24	2	30	113
Property rentable area (sqft)	184,743	1,164,250,451	311,263	8,349	81,793	3,781,045
Value per sqft ($)	230	1452185	433	29	186	742
Property walk score (0~100)	65	352259	27	0	65	100
N			6,304			

Notes: 1) Energy-star label and LEED certification data from the US Green Building Council; 2) Property walk score is obtained from Redfin and matched to the CMBS loan based on the longitude and latitude of the property. It is used in our sample match later in the analysis; 3) the office loan sample is from the original sample of nearly 90,000 CMBS loans. We focus on fixed-rate loans covered by RCA price indices (in 17 MSAs and originated in 2000 or after). We lost a small portion of the loans during geocoding and data match.

Table 2 Default Rate of Securitized Office Loans: Green vs. Non-Green Loans

	Energy-star	LEED certified	Energy-star or LEED certified, not both	Both Energy-star and LEED certified
0	16.7	16.3	16.7	16.3
1	9.4	6.0	9.5	4.8
Difference	-43%	-63%	-43%	-71%

Notes: 1) Default rate numbers in percent (%); 2) The sample includes 6,304 office CMBS loans, among which 1,001 were defaulted. 3) 673 properties are ever Energy-star labelled and 252 are ever LEED certified. Among the 718 properties that are Energy-star or LEED certified, 156 properties have both Energy-star label and LEED certificate and the rest only have one of the two green labels. 4) Default is defined as 60-day delinquency.

Table 3 Comparison of Key Variables between Green and Non-green Loans

	LTV (%)	Occupancy (%)	Value per sqft ($)	Log balance	Property age
Non-green properties	68%	95	220	16	36
Green properties	64%	93	308	17	39

Notes: 1) These are respective sample means at loan origination.

Table 4 Default Rate Difference between Green and Non-green Loans after Controls

	Modelled difference in default rate		
	Model 1	Model 2	Model 3
Energy-Star labeled	-0.475*** (-37.8%)		
LEED certified		-0.847*** (-57.1%)	
Energy-Star or LEED certified, not both			-0.310** (-28.7%)
Both Energy-Star and LEED certified			-1.111*** (-67.0%)
Control variables	Loan characteristics, property characteristics, MSA-fixed effect, and vintage-fixed effect.		
Model pseudo R-square	0.151	0.151	0.153

Notes: 1) Results from Logit models where the dependent variable is default or not during the life of the loan (up to the data collection point). 2) The list of control variables includes log loan balance, origination LTV, origination occupancy rate, amortization term, maturity term, property value per sqft, age of the property, MSA-fixed effect and vintage-fixed effect.

Table 5 Descriptive Statistics of Time-Varying Covariates

	At origination						At termination					
	Non-default			Default			Non-default			Default		
Variable	Mean	STD	Med.	Mean	STD	Med.	Mean	STD	Med.	Mean	STD	Med.
Energy-star labelled	0.02	0.14	0	0.02	0.15	0	0.10	0.30	0	0.04	0.20	0
LEED certified	0.00	0.04	0	0.00	0.04	0	0.03	0.18	0	0.00	0.05	0
Energy-star or LEED	0.02	0.15	0	0.02	0.15	0	0.11	0.31	0	0.04	0.21	0
Energy-star or LEED, not both	0.02	0.14	0	0.02	0.15	0	0.08	0.27	0	0.04	0.21	0
Both energy-star and LEED	0.00	0.03	0	0.00	0.03	0	0.03	0.17	0	0.00	0.03	0
Current LTV(%)	64.32	12.72	67.27	70.42	13.57	70.96	58.69	21.10	56.31	93.45	32.32	90.52
Current DSCR	1.72	0.55	1.58	1.56	0.34	1.53	1.65	0.61	1.54	1.25	0.43	1.25
Refinance incentive	0.01	0.08	0.01	0.02	0.10	0.03	0.25	0.10	0.27	0.26	0.12	0.25
MSA unemp. rate innovation	0.99	0.13	0.96	1.03	0.19	0.97	0.92	0.06	0.90	1.09	0.21	1.00
Vol. of 10 year Treasury rate	0.36	0.12	0.32	0.36	0.12	0.32	0.38	0.04	0.39	0.48	0.12	0.45
Vol. of CPPI	7.65	3.86	7.26	8.21	4.79	7.19	9.30	4.13	10.14	11.32	7.77	9.26
Number of observations	5,303			1,001			5,303			1,001		

Notes: 1) Current LTV is calculated based on origination LTV and MSA-level commercial property price index (CPPI) from Real Capital Analytics (RCA); 2) Current DSCR is from the operating statement of the property; in the case of missing DSCR in the operating statement, we use the nearby quarter result; 3) refinance incentive is calculated as the difference between the origination mortgage interest rate and the current prevailing mortgage interest rate; 4) MSA unemployment rate innovation is the ratio between the current quarter unemployment rate and past 6 quarter moving average; the variable is a used as a business cycle indicator (see Korniotis and Kumar, 2013).

Table 6 Impact of Green Label and Certificate: Default Hazard Model Results

	Full sample		Matched sample	
	Model 1	Model 2	Model 1	Model 2
Energy-Star labelled	-0.400**		-0.714***	
	(0.670)		(0.490)	
Energy-Star or LEED certified		-0.392**		-0.668***
		(0.676)		(0.513)
Control variables	Current LTV, current DSCR, refinance incentive, macroeconomic variables, loan characteristics, property characteristics, MSA-fixed effect, vintage-fixed effect, and baseline hazard			
Number of loans	6,304		1,004	
Number of loan-quarters	183,425		22,028	

Notes: 1) hazard ratio in parenthesis; 2) complete model results in Appendix 1; 3) the focus variable "Energy-star labelled" and "Energy-star labelled or LEED certified" are time varying variables as a property may get labelled or certified at a certain age of the loan after origination. In the full sample, among the 6,304 loans, 673 are ever Energy-star labeled and 718 are ever Energy-star labeled or LEED certified. Also, among those loans, 113 loans were Energy-star labeled at loan origination and 138 were Energy-star labeled or LEED certified at loan origination; 4) in the matched sample, 395 green loans are matched to 609 non-green loans. The match is based on property type, zip code, property value per square footage, walk score, and property Euclidian distance; 5) * for p<0.1, ** for p<.05 and *** for p<0.01.

Table 7 Correlation between the Green Variables and Contemporaneous DSCR

	Energy-Star labelled	Energy-Star or LEED certified
Current DSCR	0.077***	0.076***
Number of observations	183,425	

Notes: * for p<0.1, ** for p<.05 and *** for p<0.01.

Table 8 Impact of Green Points: Logit and Hazard Model Results

	Green properties only	
	Logit model	Hazard model
Green points	-0.714***	-0.111**
Control variables	Loan characteristics, property characteristics, MSA-fixed effect, and vintage-fixed effect.	Current LTV, current DSCR, refinance incentive, macroeconomic variables, loan characteristics, property characteristics, MSA-fixed effect, vintage-fixed effect, and baseline hazard.
N	718	21,485

Notes: 1) the focus variable "Green points" are the number of points received in the labelling and certification process (standardized respectively). In the hazard model, they are time varying as a property may get labelled or certified at a certain age of the loan after origination. 2) Among the 718 loans that are ever Energy-star labeled or LEED certified, 113 loans were Energy-star labeled at loan origination and 138 were Energy-star labeled or LEED certified at loan origination; 3) * for p<0.1, ** for p<.05 and *** for p<0.01.

Table 9 Retail Loans Default Hazard Model Results

	Full sample	
	Model 1	Model 2
Energy-Star labelled	-0.271	
	(0.763)	
Energy-Star or LEED certified		-0.392
		(0.676)
Number of loans	8,747	
Number of loan-quarters	261,939	

Notes: 1) hazard ratio in parenthesis; 2) among the 8,747 loans, 55 are ever Energy-star labeled and 61 are ever Energy-star labeled or LEED certified. Also, among those loans, only 9 loans were Energy-star labeled at loan origination and none are LEED certified at loan origination; 3) * for p<0.1, ** for p<.05 and *** for p<0.01.

Table 10 Impact of Green Label and Certificate: Rate Spread Regression

	Full sample	Matched sample
Green at loan origination	-0.111***	-0.078**
Green after loan origination	-0.067***	-0.031
Control variables	Loan characteristics, property characteristics, macroeconomic variables, MSA-fixed effect and vintage-fixed effect	
N	5,182	795
Adjusted R-square	0.756	0.736

Notes: 1) complete model results in Appendix 2; 2) * for p<0.1, ** for p<.05 and *** for p<0.01.

Table 11 Impact of Green Label and Certificate: IO periods, Amortization Term and LTV

	IO periods	Amortization term	LTV
Green at loan origination	8.495***	-19.314***	-5.262***
Green after loan origination	5.479***	1.958	-5.890***
Control variables	Loan characteristics, property characteristics, macroeconomic variables, MSA-fixed effect and vintage-fixed effect		
N	4,479	4,479	4,479
Adjusted R-square	0.663	0.508	0.203

Notes: 1) for loans with 10-year term only; 2) * for p<0.1, ** for p<.05 and *** for p<0.01.

Appendix 1 Complete Results of the Hazard Model

Covariate	Estimate (S.E.)	
	Model 1	Model 2
Energy-star labelled	-0.400**	
	(0.166)	
Energy-star labelled or LEED certified		-0.392**
		(0.163)
Current DSCR	-0.971***	-0.97***
	(0.044)	(0.044)
Current LTV	0.465***	0.465***
	(0.044)	(0.044)
Refinance incentive * lock out	0.297***	0.298***
	(0.084)	(0.084)
Refinance incentive * no prepayment restriction	0.137	0.136
	(0.086)	(0.086)
Log loan balance	0.113**	0.114**
	(0.04)	(0.04)
Origination LTV > 75%	0.184*	0.184*
	(0.073)	(0.073)
Value per sqft	-0.448***	-0.448***
	(0.066)	(0.066)
New building (age $\leq$ 10 years)	-0.112	-0.111
	(0.085)	(0.085)
Old building (age > 39 years)	-0.204*	-0.203*
	(0.085)	(0.085)
MSA unemployment rate innovation	0.398***	0.398***
	(0.056)	(0.056)
Vol. of 10-year Treasury rate	-0.232***	-0.232***
	(0.051)	(0.051)
Vol. of CPPI	-0.029	-0.029
	(0.038)	(0.038)
MSA-fixed effect	Y	Y
Vintage-fixed effect	Y	Y
N	183,425	183,425
-2LogL	15,382	15,382
AIC	15,470	15,470

Notes: * for p<0.1, ** for p<.05 and *** for p<0.01.

Appendix 2 Complete Results of the Spread Regression

Covariate	Estimate (S.E.)
Energy-star labelled or LEED certified at loan origination	-0.111***
	(0.034)
Energy-star labelled or LEED certified after loan origination	-0.067***
	(0.02)
Log loan balance	-0.046***
	(0.007)
Origination LTV > 75%	-0.073***
	(0.014)
LTV at loan origination	0.083***
	(0.007)
Occupancy rate at loan origination	-0.010
	(0.005)
Amortization term	0.000***
	(0.000)
IO periods	-0.001***
	(0.000)
Value per sqft	0.000**
	(0.000)
New building (age $\leq$ 10 years)	0.021
	(0.014)
Old building (age > 39 years)	0.028**
	(0.013)
With lockout term	0.112**
	(0.034)
With prepayment penalty	0.325***
	(0.059)
With yield maintenance term	0.004
	(0.016)
Yield slope at loan origination	0.105***
	(0.02)
Credit spread at loan origination	0.067***
	(0.011)
Vol. of 10-year Treasury rate at loan origination	0.044***
	(0.013)
Loan term = 5 years	0.484***
	(0.049)
Loan term = 7 years	0.199***
	(0.051)
Loan term =10 years	0.047
	(0.047)
N	5,354
Adjusted R-Square	0.753

Notes: * for p<0.1, ** for p<.05 and *** for p<0.01.