Home Energy Efficiency and Mortgage Risks

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Abstract

As part of President Barack Obama's Climate Action Plan, the Obama administration recently proposed that energy efficiency should be factored into mortgage underwriting upon the sale or refinancing of new and existing homes. Little empirical evidence unfortunately exists on the relationship between energy efficiency and mortgage risks. Using a unique dataset, we examine the performance of mortgages backed by ENERGY STAR-certified homes. We find that default and prepayment risks are significantly lower in such certified homes. Even for ENERGY STAR-certified homes, more energy efficiency is associated with even lower loan risks. These results offer support for taking energy efficiency into consideration in the mortgage underwriting process. Being the first of its kind, further research needs to replicate the present study with other datasets during different time periods and with alternative methodologies.

Introduction

During the past few decades, even as houses were becoming more energy efficient, energy costs per household and the total energy used in the residential sector were continuing to rise. Today, many people are living in smaller households but in larger houses, with increasing reliance on space conditioning and appliances, which results in higher energy consumption per household (Kaza, 2010). According to the Energy Information Administration's 2009 Residential Energy Consumption Survey, households spend about $230 billion each year on energy, not including the cost for transportation (Energy Information Administration, 2012). Although utility costs of urban households, on average, are one-fifth of the total housing costs, it is as much as 30 percent for rural households. Although the households in the top income quintile pay more than three times in shelter costs as the bottom quintile, they pay only 75 percent more in utility costs, suggesting that energy consumption is relatively income inelastic and that a greater burden is placed on low-income households (Bureau of Labor Statistics, 2013). Therefore, high utility costs make some households more vulnerable than others and pose greater challenges to meet other needs, such as housing-related expenses. Promoting energy efficiency in the residential sector is a mechanism for reducing utility expenses of households.

In general, energy-efficient houses have higher upfront costs because of better construction practices and use of efficient but costly appliances. For example, in their study of California homes, Kok and Kahn (2012) found that the average premium is $34,800 (about 9 percent) for green-rated homes, although the operational savings during a lifetime recoups these premiums.[1] As Jaffe and Stavins (1994) argued, however, the nonrapid adoption of energy-efficiency measures indicates that the present valuation of savings is less important to consumers than are other market and nonmarket barriers. These barriers include transaction costs, uncertainty and cost of the initial investment, and information asymmetries, all of which are still poorly understood.

Keoleian, Blanchard, and Reppe (2000) argued that, although an energy-efficient house recoups any additional premium in sales prices, the mortgage underwriting process does not account for these savings, contributing to lower adoption rates of energy-efficient measures. The Federal Housing Administration's (FHA's) Energy Efficient Mortgage program, which is designed to promote rapid adoption of efficient technologies in the residential construction sector, remains a very small program. In a recently proposed Climate Action Plan, the Obama administration suggested that the FHA would consider, "… options for factoring energy efficiency into mortgage underwriting and appraisal processes upon sale or refinancing of new or existing homes" (Executive Office of the President, 2013: 9). In this article, we focus on reasons why the mortgage underwriting process, as a matter of rule rather than exception, could account for energy efficiency and spur wider adoption of energy efficiency. In this article, we investigate whether energy-efficient homes are associated with reduced mortgage termination risks. If our hypothesis is confirmed, it would suggest that flexible mortgage underwriting could be used for borrowers living in energy-efficient homes.

Although the evidence of relationship between mortgage risks and residential energy consumption and efficiency is sparse, some research examines the combined transportation and utility burden of households and their relationship to mortgage performance. Burt, Goldstein, and Leeds (2010) theorize that mortgages on energy-efficient houses should have lower risks than those on standard houses because the savings from residential energy and transportation costs leave more income available in case of emergencies or unexpected events. Using proxy measures for transportation energy costs such as Walk Score™, Rauterkus, Thrall, and Hangen (2010) found that transportation energy savings are associated with lower mortgage delinquency risks in high-income areas but with higher risks in low-income areas. Increased vehicle ownership for households, as a proxy for higher transportation costs, increases the delinquency risks. These results contradict the earlier study by Blackman and Krupnick (2001),

[1] Green-rated homes, such as LEED (Leadership in Energy and Environmental Design) or GreenPoint, conserve energy and materials in both the operation and the construction phases.

who found that location-efficient mortgages do not have any significant effect on delinquency risk compared with conventional mortgages.[2] Data deficiencies and use of proxy metrics to capture important features of energy consumption may have led to these inconclusive and contradictory results.

In this article, we address some of the limitations of previous work and examine whether residential energy efficiency is associated with lower mortgage risks. More narrowly, we use a national sample of 71,000 loans from CoreLogic, Inc., (38 states and the District of Columbia) and examine whether two measures of energy efficiency (one discrete and one continuous) are associated with lower default and prepayment risks. In this particular article, we narrowly focus on household energy consumption and their effect on mortgage risks, leaving the effect of transportation energy burden for future work.

In this article, we first describe the different financing mechanisms for residential energy efficiency. Next, we provide an overview of the mortgage risk literature. Then, we describe the research design and methods used to examine the effects of energy efficiency on mortgage risks. In closing, we discuss the results and derive implications for future research and policy.

Household Energy Efficiency

The residential sector accounts for 20 percent of the total energy consumed in the United States (EIA, 2011). A widely cited study by McKinsey & Company suggests that energy efficiency in the residential sector has a potential to save $41 billion annually (Granade et al., 2009). It is, thus, not a surprise that building energy efficiency is considered the “fifth fuel” and is actively promoted through government policy and voluntary action.

One widespread way of promoting residential energy efficiency in the United States is through the U.S. Environmental Protection Agency’s (EPA’s) ENERGY STAR program for appliances, commercial and industrial buildings, and new home construction. The market penetration of the ENERGY STAR label in new housing construction is noteworthy—25 percent of new U.S. housing starts were ENERGY STAR-certified in 2011 (EPA, n.d.a). Homes awarded the ENERGY STAR label are at least 15 to 20 percent more energy efficient than the typical new home and must meet rigorous guidelines for a high-efficiency thermal enclosure (such as windows and insulation); heating, ventilation, and air-conditioning (HVAC) system; and appliances, as well as a comprehensive water management system.

To earn an ENERGY STAR rating, homes must also undergo an inspection by a certified home-energy rater who examines construction plans and conducts post-construction evaluations, including a blower door test (to test the envelope infiltration) and a duct infiltration test. The rater uses these data to assign the home a relative performance score, called the Home Energy Rating System (HERS) Index Score. The index is normalized to the climatic zone, size, and type of the house. A home built to current market standard (2006 International Energy Conservation

[2] This study is limited to FHA loans in Chicago, Illinois. Because the mandate of FHA is to increase homeownership among low-income households, the results from this study may not be generalizable.

Code standard) is given a rating of 100.[3] A lower HERS Index Score for a house indicates higher energy efficiency; that is, a HERS rating of 60 indicates that the house is 40 percent more energy efficient than a similar one that is constructed to the current market standards. A score of 0 corresponds to a net-zero-energy home. A standard resale house has a rating of 130. A HERS rating of 85 is typically required to achieve ENERGY STAR certification. Residential Energy Services Network (RESNET), a standards-making body that certifies the raters and the procedures, is responsible for ensuring consistency and quality in certification.

Within the United States, other comprehensive, but smaller or regional, programs promote energy efficiency in new housing construction, such as Leadership in Energy and Environmental Design (LEED) for Homes, National Association of Home Builders' Green Building Standard, EarthCraft (in the Southeast), Earth Advantage Label (in the Pacific Northwest), and GreenPoint Rated certification (in California).[4] These rating systems generally exceed the building performance of ENERGY STAR and promote comprehensive green building technologies and materials.

Nearly all rating systems rely on some version of modeled and hypothetical energy use. It is important to note that, although the construction is tested for leakage and other inefficiencies, the rating systems do not account for actual post-occupancy energy use.[5] Household energy consumption, although dependent on building envelope and appliances, also crucially depends on occupants' behavior and use patterns. As Stein and Meier (2000) pointed out, although ENERGY STAR certification is a useful predictor of a home's relative energy efficiency, the difference between a homeowner's expected, modeled, and realized energy savings may vary. This consideration plays an important role in qualifying the conclusions drawn in this article. Nevertheless, ENERGY STAR-certified houses, on average, are expected to save energy compared with conventional homes.

Financing Energy Efficiency in the Residential Sector

Promoting energy efficiency in the residential sector requires providing mechanisms to offset the higher upfront costs generally associated with energy-efficiency measures. Although many of these measures have a reasonable payback period, some barriers, such as transaction costs and information asymmetries, prevent rapid and widespread adoption of energy efficiency (Gillingham, Newell, and Palmer, 2009). Part of the challenge for public- and private-sector programs is to provide mechanisms, including innovative financing mechanisms that will overcome these barriers.

One way to finance energy efficiency is through grants geared toward energy-efficiency retrofits. A well-known and long-running program is the Weatherization Assistance Program, or WAP,

[3] Fairey et al. (2000) provided a historical overview of the development of HERS ratings in the United States.

[4] As of 2012, only about 15,000 U.S. homes were LEED certified. On average, about 400,000 new homes are constructed every year in the United States. (See U.S. Census Bureau, n.d.; USGBC, 2012.)

[5] This performance statement is true for the residential sector. ENERGY STAR ratings for the nonresidential sector rely on building performance by comparing the actual energy use to other buildings of similar type in that year.

that offers grants to qualified low-income families for the purpose of weatherization. State-sponsored energy-efficiency loan funds are also in vogue. They, too, have grown recently using funding from the American Recovery and Reinvestment Act of 2009. The National Association of State Energy Officials tracks 79 such funds that are available in 44 states. The total amount of funding dedicated to state energy-revolving-loan funds covered in their database is over $2 billion (NASEO, n.d.).[6]

However, residential energy efficiency is predominantly funded by the rate payer. Total spending on U.S. ratepayer-funded energy-efficiency initiatives more than doubled in the latter half of the past decade—from $2 billion in 2006 to $4.8 billion in 2010. Two-thirds of the total was concentrated in only 10 states, however, with California, New York, New Jersey, Massachusetts, and Washington as leaders (Barbose et al., 2013; Barbose, Goldman, and Schlegel, 2009). One such initiative, on-bill financing, is provided by the utilities as part of their efficiency efforts. Utilities provide zero- (or near-zero) interest loans for qualified customers, which are then recouped through a line item in the utility bill. Most of these programs are primarily targeted at nonresidential customers, however, rather than homeowners because of the complexity of collection and resistance on the part of utilities (Fuller, 2009). In 2011, New York State authorized residential on-bill loans, which are currently being implemented by the New York State Energy Research and Development Authority (NYSERDA) in cooperation with New York utilities (Henderson, 2012).

Property Assessed Clean Energy (PACE) bonds are a financing mechanism that uses locally issued tax bonds to fund residential energy-improvement activities. The funds are gradually paid back (more than 20 years or so) through special taxation placed on the property through a lien. In the event of resale, the new property owners take on the responsibility of special taxes. Because of the first lien placed on the property, secondary market institutions have been reluctant to embrace mechanisms such as PACE bonds, thus limiting their widespread adoption to date. A recent Ninth Circuit Court ruling effectively ended the involvement of PACE in the residential sector.[7]

By far, the most widely used mechanism is direct borrowing. Most energy improvements for existing homes can be financed through consumer loans, a home-equity loan secured by property, or by traditional or specialized mortgages. Although not widely available, energy-improvement mortgages (EIMs) enable the homeowner to fold the costs of energy improvements into the mortgage.

The financing mechanisms listed previously are geared toward improving the energy efficiency of existing homes; they are not set up to offset the higher upfront costs of new houses that are energy efficient and make them affordable. By contrast, energy-efficient mortgages (EEMs) enable lenders to have flexibility in the debt-to-income ratio and other underwriting considerations so that borrowers can qualify for larger loans or obtain a lower interest rate. EIMs and EEMs both are relatively small because of the transactional complexity and lack of information

[6] These funds include financing for both energy efficiency and renewable energy projects.

[7] *County of Sonoma* v. *Federal Housing Finance Agency*. 2013. (Vol. 710). Court of Appeals, 9th Circuit.

(EPA, 2010) Furthermore, very few lenders currently offer them, except for FHA and Veterans Benefits Administration mortgages. For example, only three such lenders exist for Texas and only two for Arizona—the two states with the largest number of new ENERGY STAR residences in 2011 (EPA, n.d.b).

The programs and financing options listed previously have grown and show promise but, at less than $6 billion in aggregate, reflect poor market penetration.[8] Of all these mechanisms, EEMs and EIMs have the greatest potential to encourage energy efficiency because they rely on the mainstream financial system. Because other mechanisms rely on funding from multiple sources, institutional fragmentation creates barriers for widespread adoption. The limited availability and appeal of EIMs and EEMs, in large part, may be because of the uncertainty and lack of information about their inherent risks. If, indeed, mortgages on energy-efficient homes have lower risks than those on less efficient homes, a lower pricing or more flexible underwriting standard is likely to result in an increased demand for these products. In addition, with more accurate information on risks, lenders may be able to more effectively develop and tailor these mortgage products. In a wide-ranging study, T'Serclaes (2007) showed that, contrary to popular expectations, the more important financial barrier than the availability of funding is the financiers' belief of higher risk exposure, which prevents widespread adoption of energy efficiency. She suggests, "… [U]ncertain quantification of energy benefits, small size of investments as well as difficult standardization of investment and continuing debate on the nature of discount rate, still discourage investments in energy efficiency" (T'Sercales, 2007: 6).

Estimating Mortgage Default and Prepayment Risks

Mortgage lending can play an important role in promoting energy efficiency by making it more mainstream and in addressing some of the problems associated with financing energy-efficient residences. For this reason, it is important to understand the risks inherent in such lending. Many insights fortunately have been gained from a large number of mortgage termination studies that can be applied to better understand the relationship between energy efficiency and risks. Previous studies focused on two aspects of mortgage risks: default and prepayment. Mortgage default occurs when mortgage borrowers stop making scheduled payments and when certain conditions required by law occur.[9] Prepayment occurs when borrowers prematurely pay off loans. From a lender's perspective, prepayment can be considered a risk because, when borrowers prematurely pay off the loan, often when interest rates fall, the lender does not realize the expected stream of payment and return. Default and prepayment both can lead to a loss to lenders, although, given the relative size of the loss, researchers and practitioners tend to focus more on the risk of default than on the risk of prepayment (Quercia and Stegman, 1992).

[8] Mortgage debt as of June 2013 in the United States for single-family residences was in excess of $9.5 trillion, although the estimated value of owner-occupied housing stock is close to $18.5 trillion (Federal Reserve, 2013; n.d.).

[9] In the United States, laws governing the conditions of default and foreclosure can differ by jurisdictions. (See, for example, Cutts and Merrill, 2008.)

Researchers have advanced two complementary frameworks to explain these two risks. One framework has focused on the financial benefit of options (Foster and Van Order, 1984; Kau et al., 1992). This group of studies treats default and prepayment as financial options. The framework assumes that borrowers make constant evaluations about the financial benefits of these options and will exercise them once the options become beneficial. For instance, regarding default, borrowers are expected to consider their equity position: borrowers who owe to the lender more than the house is worth, net of costs, are expected to be more likely to default than those who have positive equity positions. This explanation, although powerful in explaining certain key aspects of mortgage performance, does not seem to fully explain why borrowers stop making their mortgage payments. During the past two decades, a complementary view has emerged in which most borrowers are said to evaluate their equity position (or option) only in the event of a crisis or trigger event, such as job loss or divorce (Vandell, 1995). Most recent studies of default use a combination of these two frameworks—the option-based framework and the trigger-event framework.

Researchers have found evidence empirically supporting the complementary views of the option-based and adverse trigger-event frameworks. The loan-to-value (LTV) ratio, value of the prepayment option, and local unemployment rates have been found to have consistent effects on both mortgage default and prepayment. Also, certain characteristics of the borrower and the financial and servicing institutions have a consistent effect. For instance, Quercia, Pennington-Cross, and Tian (2012) found support for the importance of current LTV ratio, borrower credit, income, and unemployment. As a rule, ability to pay (captured by debt-to-income ratio) has been omitted from most loan termination studies because of lack of variation in the variable in the available samples.[10] Consistent with previous works, we use 3 months late in payments (90 days delinquent) to model the default decision. To control for unobserved quality differences of loans generated after the onset of the recent housing crisis, we incorporate an indicator for loans originated during or after 2006.

The savings resulting from energy efficiency, as previously discussed, can be viewed as a cushion to unanticipated crises or adverse events that could make mortgage repayment more difficult. It is also likely that homeowners in the market for efficient homes weigh the long-term savings derived from energy efficiency against the short-term higher costs, thus reflecting a higher degree of financial savvy. On the basis of the mortgage termination literature, we expect mortgages on energy-efficient homes to have a lower probability of default than those on less efficient ones.

Research Design and Methods

To deal with the right censoring, researchers often use hazard analysis in mortgage evaluation. In such an analysis, researchers estimate the conditional event probability (hazard); that is, they estimate the probabilities of default and prepayment, conditional on surviving to date, as

[10] Two exceptions include Quercia, Pennington-Cross, and Tian (2012) and Berkovec et al. (1998).

statistically defined. Default and prepayment are considered competing risks because, when borrowers act on one, they preclude action on the other. In the context of this competing-risk model, consider two termination risks: default D and prepay P. The hazard $\lambda_i^r(t|X_i(t), \beta_r, \theta_r)$ for individual i, risk $r + D, P$, given characteristics $X_i(t)$, parameters $\boldsymbol{\beta}_r$, and unobserved heterogeneity parameter $\boldsymbol{\theta}_r$ is defined as

$$\lambda_i^r(t|X_i(t), \beta_r, \theta_r) = \lim_{\Delta t \to 0} \frac{Pr(t < T_i^r < t + \Delta t | T_i^r \geq t, X_i(t), \beta_r, \theta_r)}{\Delta t}. \quad (1)$$

With a discrete time assumption, a multinomial-logit model is often used to estimate the previous equation.

We use a treatment-control research design to estimate the differences in mortgage termination risks. We use the loan information for ENERGY STAR (treatment) and non-ENERGY STAR (control), supplemented with information about factors that contribute to household energy consumption. We adopt the competing risk framework of mortgage terminations and estimate the effect of prepayment and mortgage default simultaneously (Quercia and Spader, 2008). We use a multinomial logit model to quantify these risks relative to one another and to test whether risks of loans of energy-efficient homes are different from those of energy-inefficient homes.

$$\ln\left(\frac{\Pr(Y_i = D)}{1 - \Pr(Y_i = D)}\right) = \alpha_D + \boldsymbol{\beta}'_D\boldsymbol{E} + \boldsymbol{\gamma}'_D\boldsymbol{X} + \boldsymbol{\tau}'_D\boldsymbol{T} + \boldsymbol{\vartheta}'_D\boldsymbol{S} + \delta_D C + \epsilon_D, \text{ and} \quad (2)$$

$$\ln\left(\frac{\Pr(Y_i = P)}{1 - \Pr(Y_i = P)}\right) = \alpha_P + \boldsymbol{\beta}'_P\boldsymbol{E} + \boldsymbol{\gamma}'_P\boldsymbol{X} + \boldsymbol{\tau}'_P\boldsymbol{T} + \boldsymbol{\vartheta}'_P\boldsymbol{S} + \delta_P C + \epsilon_P, \quad (3)$$

where Pr is the probability, E is a set of variables of the house that relate to energy consumption (such as square feet and climate), X is the standard set of explanatory variables from the mortgage termination literature (such as LTV ratio and unemployment rate), T is the set of dummy variables representing age of loan, and S is the set of dummy variables representing other fixed effects (such as state). C is an indicator variable referring to the treatment (ENERGY STAR/regular). $\boldsymbol{\delta}$s are the estimates of interest.

To understand whether the extent of energy efficiency matters, we also compare the risks of default of mortgages on ENERGY STAR homes for which a HERS Index Score is available. These HERS ratings are included in the model as a continuous variable (0 to 85), thus enabling us to examine whether better energy efficiency (lower HERS rating) is associated with lower mortgage risks. Thus, instead of an indicator variable for treatment, we use a HERS rating variable. Because the HERS model primarily compares the loan performance of ENERGY STAR residences, the results may be interpreted as an argument for considering the degree of energy efficiency in the mortgage underwriting process.

Data Description

The study described in this article uses a carefully constructed sample of loans across the nation. First, we directly obtained addresses of 226,962 HERS-rated homes from RESNET's database and from individual HERS providers. These houses obtained a HERS rating from

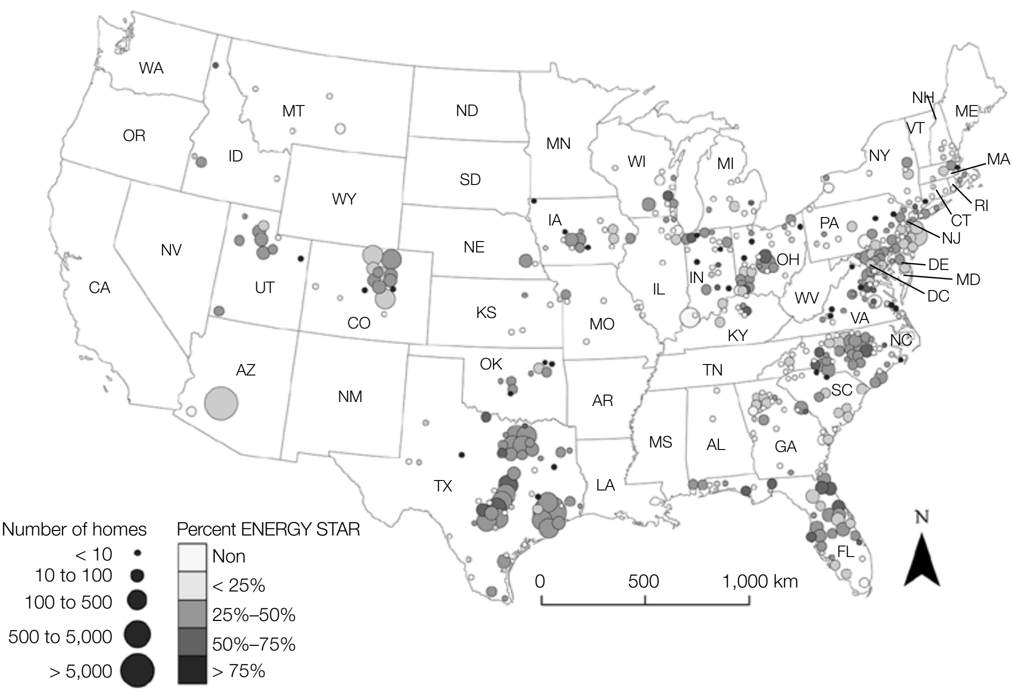
2000 through 2010. Because of data-privacy restrictions,[11] inconsistent addresses, and low market share of HERS-rated homes, the states of Alaska, Arizona, California, Louisiana, Maine, Minnesota, North Dakota, Oregon, South Dakota, Tennessee, West Virginia, and Wyoming are excluded from the sample (exhibit 1).

The addresses from this sample are matched to the addresses in the CoreLogic, Inc. loan level database. For each matched record within the ZIP Code, loan information of approximately three other loan records was also included in the sample. It is assumed that these houses are not energy efficient and are considered part of the "control" group. Furthermore, the sample is restricted to single-family, owner-occupied houses for which loans originated from January 2002 and for which loans were used only for purchase.

CoreLogic, Inc., provided all the loan-level variables, including payment stream. Prepayment is defined as loans being paid off prematurely. Consistent with previous work, 90 days of delinquency is the marker used for defining mortgage default. The key risk determinants at origination are included in the model: the borrower's credit score (FICO—that is, Fair Isaac Corporation credit scoring model), LTV ratio, loan type (conventional/government and

Exhibit 1

Geographical Distribution of the Sample (ENERGY STAR and Non-ENERGY STAR Homes)



km = kilometers.

[11] Although energy-efficient homes enjoy a large market share in California, consumer privacy restrictions prevented the access to address and rating data for California HERS-rated homes.

nonprofit-organization backed),[12] local unemployment rate, neighborhood income, house value relative to the area median value, size of the house, and age of the house (exhibit 2).[13]

We constructed the neighborhood-level variables from multiple sources. We used the CoreLogic, Inc. MarketTrends database to include variables such as average income and average home sales price. We retrieved unemployment rate, median housing value, and household income from the 2006 through 2010 American Community Surveys at the census-tract level (U.S. Census Bureau, 2012). We used geographic weighting to aggregate the data to the ZIP Code level. Such aggregations were necessary because the spatial resolution of the MarketTrends database was at the ZIP Code level.

In addition to including the ENERGY STAR and HERS rating in the analysis, we include a number of other energy-use-related variables, including number of cooling degree-days, number of heating degree-days, electricity prices, and area of the house. We obtained weather data, such as average annual (during the past decade) cooling degree-days and heating degree-days, from the National Climatic Data Center. We assigned each weather station to a block group and then aggregated data to the ZIP Code level through geographic weighting. As a proxy for the cost of energy, we used electricity prices, which were obtained at a ZIP Code level that is complied for investor-owned utilities (IOU) and non-IOU utilities by National Renewable Energy Laboratory and Ventyx. For the approximately 1,300 ZIP Codes that are without the price data, we estimated them from neighboring ZIP Codes and through manual lookup.

Exhibit 2

Average Values for ENERGY STAR and Non-ENERGY STAR Homes in the National Sample

Variables	Non-ENERGY STAR Homes	ENERGY STAR Homes
n	46,118	24,944
Age of the house (years)	13.2	4.2
Area of the house (square feet)	2,183	2,283
Origination LTV ratio [Original as in Ex. 3 and 4?]	0.91	0.93
FICO score (in 100s)	7.06	7.05
ZIP Code average income (dollars)	73,741	73,550
ZIP Code unemployment (percent)	6.4	6.4
Time to default [(days)?]	30.6	29.9
Percentage of defaults	15.2	8.9
Percentage of prepayment	32.2	22.1
Sales price (dollars)	218,461	221,919
Cooling degree-days	1,486	1,494
Heating degree-days	1,308	1,199
Electricity price (¢/kWh)	12.2	12.1

¢ = cents. FICO = Fair Isaac Corporation (credit scoring model). kWh = kilowatt hour. LTV = loan-to-value.

[12] Government and special program loans include FHA loans and other special programs run by government agencies and nonprofit organizations (which are designed for traditionally underserved borrowers who would otherwise have difficulty obtaining credit in the conventional market).

[13] Option-based theory suggests including the value-of-prepayment option in estimating the probability of prepaying. The outstanding loan balance is not available in our data, however. Because we do not have complete loan delinquency information, imputing the loan balance would cause serious endogeneity issues. We experimented with crude measures of interest rate differences, but the results are not sensible.

We then added these ZIP Code-level neighborhood variables to the address-level loan information. Privacy restrictions dictated that CoreLogic data were made available to us after stripping identifying information such as addresses.

Overall, the final analysis file for the baseline model includes information on about 71,000 loans. This number results from limiting the sample to 30-year fixed-rate mortgages,[14] the first 5 years after origination, and loans with original LTV ratios between 50 and 150 percent and from excluding cases with missing values in key determinants. We include all 71,000 loans in our baseline-model estimation. We include the ENERGY STAR homes (about 35 percent or 21,000 loans) only in the model that examines the relationship between the degree of energy efficiency and mortgage termination risks.

ENERGY STAR homes descriptively show lower incidences of default and prepayment. About 22 percent of the ENERGY STAR home loans prepaid compared with 32 percent for the non-ENERGY STAR group. Although mortgages on only 9 percent of ENERGY STAR homes have similarly experienced default (on average after 29.9 months), about 15 percent of mortgages on the non-ENERGY STAR homes group did (on average, after 30.8 months). Other notable differences include the fact that ENERGY STAR houses are newer than other homes and, although the average ENERGY STAR house is larger, the price per square foot is remarkably similar between the two groups (about $106 per square foot). As for the rest of the key variables, treatments and control groups each have similar characteristics.

From the literature, we expect that a higher FICO score is negatively associated with default risk and positively associated with prepayment risk. We also expect that a special purpose loan should carry a higher risk of default and that default risks should go up in areas with higher unemployment, which are mitigated in areas of higher incomes. We expect that a disproportionately expensive house is likely to carry a lower risk of default and a higher risk of prepayment, because it reflects the underlying borrower's characteristics.

Energy Efficiency Is Associated With Lower Mortgage Risks

Overall, the findings are consistent with previous work and expectations. In the baseline model, we examine the relationship between the ENERGY STAR rating and the mortgage risks (exhibit 3); that is, when C is the indicator variable that represents whether a home has ENERGY STAR certification. To account for the distributional differences in age, we also restrict the sample to houses that were built in the past decade. The findings are similar in direction and significance as those presented here, and, therefore, the results are robust to the exclusion of older homes.[15] To further examine the effect of relative efficiency on mortgage risks, we examine the subsample of ENERGY STAR-certified houses for which we have a

[14] Adjustable-rate mortgages, or ARMs, and other types of loans require panel data that track the payment schedule and time-varying attributes. Such data are not available and the models used in the study are not suitable to study such mortgages, but such a study should be considered in future work.

[15] In the following paragraphs, we discuss only the results that use the complete dataset, because post-research design restrictions of the sample (such as limiting to post-2000 homes) could lead to biased results. The results of the regressions for such subsamples are presented in exhibit 3 only for robustness check and should be interpreted with caution.

Exhibit 3

Base Model (ENERGY STAR Versus Non-ENERGY STAR)

Variable	All Data				Post 2000 Homes			
	Default		Prepay		Default		Prepay	
	Estimate	Odds Ratio	Estimate	Odds Ratio	Estimate	Odds Ratio	Estimate	Odds Ratio
Intercept	8.91*** (0.37)		1.94*** (0.26)		11.32*** (0.45)		3.21*** (0.32)	
FICO score (in 100s)	– 1.42*** (0.02)	0.24	0.09*** (0.02)	1.10	– 1.39*** (0.03)	0.25	0.14*** (0.02)	1.15
Loan origination after 2006	– 2.92*** (0.05)	0.05	– 3.03*** (– 0.04)	0.05	– 2.96*** (0.06)	0.05	– 3.06*** (0.06)	0.05
Original LTV ratio	0.79*** (0.17)	2.20	– 1.51*** (– 0.12)	0.22	0.29 (0.2)	1.34	– 1.72*** (0.14)	0.18
Loan type	1.31*** (0.04)	3.72	0.33*** (– 0.03)	1.39	1.25*** (0.04)	3.48	0.23*** (0.03)	1.26
ZIP Code average unemployment	0.03*** (0.01)	1.03	– 0.04*** (0.00)	0.96	0.02*** (0.01)	1.02	– 0.05*** (0.01)	0.95
ZIP Code average income	0.00*** (0.00)	1.00	0.00*** (0.00)	1.00	0.00*** (0.00)	1.00	0.00*** (0.00)	1.00
House price relative to ZIP Code sales price	– 0.13*** (0.03)	0.87	0.16*** (0.02)	1.18	– 0.26*** (0.04)	0.77	0.15*** (0.02)	1.16
Age of the house	– 0.01*** (0.00)	0.99	– 0.01*** (0.00)	0.99	– 0.24*** (0.01)	0.79	– 0.16*** (0.01)	0.85
ENERGY STAR certification	– 0.39*** (0.03)	0.68	– 0.32*** (0.02)	0.73	– 0.65*** (0.03)	0.52	– 0.52*** (0.03)	0.60
	N = 71,062. Log likelihood = – 52,007.6				N = 56,787. Log likelihood = – 40,447.8			

FICO = Fair Isaac Corporation (credit scoring model). LTV = loan-to-value.

**** $p \leq .001$.*

Note: Standard errors are in parentheses.

HERS rating (exhibit 4). In addition to including the variables from the baseline model, the HERS model incorporates additional variables that capture local energy-use characteristics. These characteristics include cooling degree-days, heating degree-days, electricity price, and square footage of the house.

ENERGY STAR certification is associated with substantial and significant reduction of the default and prepayment risks (exhibit 3). The odds of a mortgage default on an ENERGY STAR residence, *ceteris paribus,* are one-third less than those on a home in the control group. A mortgage on an ENERGY STAR residence is also one-fourth less likely to be prepaid. Regarding whether the extent of energy efficiency matters (HERS rating), the findings are consistent with expectations (exhibit 4). The degree of energy efficiency matters; a 1-point decrease in the HERS score is associated with a 4-percent decrease in the odds of default and a 2-percent decrease in the odds of prepayment. This finding suggests that mortgages on more efficient homes exhibit even lower mortgage risks than those on their less efficient but still ENERGY STAR-rated counterparts.

Exhibit 4

HERS Model (only with ENERGY STAR homes)

Variable	Default Estimate	Default Odds Ratio	Prepay Estimate	Prepay Odds Ratio
Intercept	10.25*** (1.19)		– 0.49 (0.74)	
FICO score (in 100s)	– 1.68*** (0.06)	0.19	0.24*** (0.04)	1.27
Loan origination after 2006	– 3.76*** (0.18)	0.02	– 2.29*** (0.15)	0.10
Original LTV ratio	0.30 (0.44)	1.35	– 1.19*** (0.25)	0.30
Loan type	0.58*** (0.09)	1.78	0.22*** (0.06)	1.24
ZIP Code average unemployment	0.02 (0.01)	1.02	– 0.05*** (0.01)	0.95
ZIP Code average income	0.00*** (0.00)	1.00	0.00* (0.00)	1.00
House price relative to ZIP Code sales price	– 0.18** (0.08)	0.83	0.10** (0.04)	1.11
Cooling degree-days	0.00 (0.02)	1.00	– 0.07*** (0.01)	0.93
Heating degree-days	– 0.04** (0.02)	0.96	0.00 (0.01)	1.00
Electricity price	0.01 (0.01)	1.01	– 0.02*** (0.01)	0.98
Area of the house	0.01** (0.00)	1.01	0.02*** (0.00)	1.02
Age of the house	– 0.01 (0.02)	0.99	– 0.07*** (0.01)	0.94
HERS score	0.04*** (0.01)	1.04	0.02*** (0)	1.02
	N = 21,094. Log likelihood = –12,822.26.			

FICO = Fair Isaac Corporation (credit scoring model). HERS = Home Energy Rating System. LTV = loan-to-value.

** p ≤ .10. ** p ≤ .05. *** p ≤ .001.*

Note: Standard errors are in parentheses.

As a rule, the other predictors in both models exhibit the expected effects. The borrower's credit score (FICO) is significantly and positively associated with prepayment and negatively associated with default in the baseline and the HERS models. The original LTV ratio exhibits significant and positive effects on default and negative effects on prepayment. Controlling for the state-fixed effects, the effect of original LTV is insignificant in the HERS model for default, although increasing original LTV reduces the prepayment risk. In this dataset, conventional loans have higher default and prepayment risks compared with government-backed and non-profit loans, probably because the loans tend to carry more favorable terms and servicing. Local unemployment rates are positively associated with default risks in the baseline model and negatively associated with prepayment risks in both models. Although higher income neighborhoods increase the default and prepayment rates, the effects are substantively small. This result is likely because of the coarseness of the neighborhood that evens out any spillover effects. Older houses are both less likely to default and prepay, possibly reflecting the underlying characteristics of borrowers who prefer these houses. Finally, houses with values higher than the neighborhood mean exhibit lower default and higher prepayment propensities, reflecting the underlying income effect.

Energy prices do not seem to have an effect on the default likelihood but do negatively affect prepayment risks within ENERGY STAR homes (exhibit 4); that is, higher energy costs reduce the risk of prepayment. Controlling for the relative price of the house, larger houses have higher prepayment and default risks. Age-of-loan data are included as a set of dummies in the models. The older the age of the loan, the more likely is the risk of default. Dummies for states are also used in the models to control for the state-fixed effects are nearly all statistically insignificant in the baseline model.[16] These model results are qualitatively consistent with other specifications not presented here and, hence, the results appear robust.

Implications for Public Policy and Research

Interest in home energy efficiency is growing in academic and policy settings. For example, President Obama recently proposed incorporating home energy efficiency into the mortgage underwriting process in his Climate Action Plan. The empirical findings of this article offer strong support for this policy proposal. The models suggest that mortgages on energy-efficient homes have significantly lower risks than those on less efficient homes, yet mortgage-underwriting practices do not reflect this fact. We find that mortgages on energy-efficient homes are associated with lower mortgage risks. Default risks on these mortgages are about one-third lower than those in the control group. We also find that the extent of energy efficiency matters: (as captured by the HERS rating) the more energy efficiency, the lower the risks.

Because the findings are consistent among different model specifications and different types of subsamples, we can derive a number of implications for policy and lending practices. First, lenders may want to require an energy audit or energy rating during the process of mortgage underwriting. In the same manner that appraisals calculate the value of the home, an energy-rating determination could define other important characteristics of the loan, including the debt-to-income ratio. Requiring energy audits as part of the mortgage underwriting process would help homeowners make informed decisions about energy-efficiency investments and likely promote long-term efficiency of the house rather than a single-time certification. This requirement alone is likely to increase the energy performance of the housing stock.

Second, lenders and secondary market investors should take into account the energy efficiency of the home used as collateral for the loan in the underwriting decisions. For instance, they may permit a higher debt-to-income ratio, lower FICO score, or reduction in the interest rate. This and similar approaches would enable borrowers to obtain larger loans. This approach

[16] These results are not presented in the tables for the sake of brevity. A complete set of results is available from the authors.

would increase affordability for many borrowers, especially in high-cost areas. Loan-level price adjustments (LLPAs) could also be used to account for mortgages on energy-efficient homes. Moreover, when possible, lenders should consider a HERS or similar rating that accounts for degrees of energy efficiency in a unit as well.

According to a study by the Joint Center for Housing Studies at Harvard University (JCHS, 2013), two-fifths of home-remodeling spending is for building envelope replacements and system upgrades (including electrical and HVAC systems). Given that this market was valued at $275 billion in 2011, these upgrades represent about a $100 billion investment by consumers that can be geared toward energy efficiency. One way to promote these energy-efficiency investments is to consider the underwriting rules for the home-improvement loans by factoring in the decreased risk associated with energy-efficient homes. Another way is to find mechanisms to encourage time-of-sale improvements on energy-efficiency measures. In particular, this effort is likely to help lower income borrowers, who tend to purchase older homes that are often less energy efficient than those built in more recent years. The EPA should encourage more lenders to join the ENERGY STAR program to broaden the consideration of energy efficiency in mortgage underwriting. The low numbers of lenders associated with the ENERGY STAR program should be addressed.

One criticism of the ENERGY STAR program[17] in the green building community is that the standards of the program are too low to merit incentives (Hassel, Blasnick, and Hannas, 2009). One way of promoting energy efficiency is to move toward performance-based metrics rather than design-based certifications (as the ENERGY STAR program does). Most of the narrowing gap between the utility savings of ENERGY STAR homes and those without that rating can be attributed to overall energy-efficiency improvements in more recently built housing. Furthermore, energy efficiency is not synonymous with conservation, which is likely to reflect household propensities. Although this article does not directly use the realized energy savings in mortgage performance, other studies show that standards for ENERGY STAR could be tightened, including moving toward more performance-based approaches. If the goal is to reduce energy consumption, encouraging energy efficiency may not be sufficient and should be complemented with incentives to increase conservation. It could very well be that households that have a propensity to conserve pose lower mortgage risks. Future studies could more thoroughly examine this effect.

Future work needs to address a number of issues associated with this research. It needs to address the endogeneity issue common in most mortgage-performance studies. Mortgage borrowers who reside in energy-efficient homes may simply be more financially able than those who own less efficient homes. Panel data that track the borrower’s income and market conditions are not available; such data would enable us to tease these effects. It is important to recognize that the energy savings of energy-efficient homes may not cause the reduction in risk. What we have demonstrated in this work is the association between reduction in risk and energy efficiency, which could very well be reflective of the underlying borrowers’

[17] A recent Government Accountability Office report found that the ENERGY STAR certification process for products could also be strengthened (GAO, 2010).

characteristics. Many borrowers' characteristics, such as income and employment status, are not available in the dataset. We included a number of ZIP Code-level variables as proxies for individual variables. Cognizant of ecological fallacy risks, we do not derive implications from the inclusion of these variables. Future work needs to address these data limitations. Nevertheless, to our knowledge, this study is the first to demonstrate the association. Future studies should be designed to tease out the evidence for causal mechanisms.

Many important states, such as California, are missing for our analyses because of data availability. Furthermore, different states and local governments have different building standards that make ENERGY STAR certification more or less easier to achieve. Such differences may account for differential market penetration of the ENERGY STAR label for new homes and may affect the mortgage risks. Although we account for state-fixed effects in our models, more research should be done to address these limitations. We believe, however, that our results reflect the mortgage termination behavior in many parts of the country.

Future research also needs to examine additional measures of energy efficiency. Although HERS can predict average energy costs in general, individual ratings, especially for older houses, are largely uncorrelated with the energy costs (Stein and Meier, 2000). A difference exists between energy conservation and energy efficiency; while the former is primarily related to the behavioral response of the consumer, the latter is about the relative efficiency of equipment and built environment. If the main goal of public policy is to reduce energy consumption, rather than promoting energy efficiency, then alternative measures that more completely capture foregone demand from behavioral changes and changes in consumption patterns should be considered for their effects on mortgage risks. Future research could also use a broader sample to study the effect on risk, such as other rating systems that promote more comprehensive green building strategies. Overall, however, we believe the findings in this article are robust and consistent enough across different model specifications to warrant further examination.

In general, the findings suggest that discrete and continuous measures of energy efficiency each are related to loan performance risk, even though more research is necessary to firmly establish causal links. Low energy burden is potentially associated with lower risks for default. The lower risks associated with energy efficiency could be taken into consideration when underwriting mortgage risks. Contingent on confirmation by other studies, Congress could consider the findings in their deliberations of the SAVE Act, the bill proposed to improve the accuracy of mortgage underwriting used by federal mortgage agencies by ensuring that energy costs are included in the underwriting process. Similarly, market stakeholders, such as Fannie Mae and Freddie Mac, could encourage underwriting flexibility for mortgages on energy-efficient homes; for instance, by adjusting LLPAs or their equivalents accordingly. These measures have potential to dramatically increase the adoption of efficiency, contribute to reduction of the energy burden, and increase the quality of life for households across the United States.

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