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## Location Efficiency and Mortgage Risks for Low-Income Households

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### ABSTRACT

Household energy expenditures, especially for transportation, are fairly inelastic. Their effects on low-income households may be significant, due to the potential for energy consumption to displace other types of consumption when energy prices rise. Using accessibility as a proxy for lower transportation costs, we test the hypothesis that low- and moderate-income residents are less likely default when they are located in more accessible places. We find that regional accessibility has almost no effect on risks of default, but local job diversity has moderate mitigating effect.

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Affordability; low-income housing; mortgage risks; location efficiency

Around the late 1990s and early 2000s, a push to incorporate location efficiency into mortgage underwriting led to the creation of various energy-efficient mortgage products, such as location-efficient mortgages (LEM) and smart commute mortgages. These programs have not been a success and were discontinued in 2008 (Center for Neighborhood Technology, 2013). Despite this discontinuation, location efficiency—a measure of neighborhood compactness and diversity with high accessibility—continues to be the topic of policy conversations (Henry & Goldstein, 2010). Household energy expenditures, including transportation, have represented about one quarter of average household expenditures in the last few years (Bureau of Labor Statistics, 2013). It is reasonable to expect that low-income households might benefit from transportation expenditure savings, which could offset some mortgage risks. In this article, we examine the relationship between location efficiency and mortgage risks for low-income households. We find that increasing regional accessibility does not necessarily reduce mortgage risks, whereas increasing neighborhood job diversity does.

In this study, we examine the relationship between indicators of household location efficiency and mortgage performance by taking advantage of a unique data set of borrowers who received mortgages through the Community Advantage Program (CAP). The data collected as part of this program allow detailed location metrics and other household information to be linked to mortgage transaction data. More importantly, this program was targeted toward low- and moderate-income and minority homeowners, which makes the data ideal for testing the hypothesis that location efficiency is an important determinant of mortgage performance for low-income households. We find that regional accessibility is a poor predictor of mortgage risks whereas local accessibility does reduce default risk, but only slightly.



## Background

### **Mortgage Risks, Lending Practices, and Housing Affordability**

The mortgage plays an important role in determining the home purchase experiences of households. Lenders evaluate the risks of default and prepayment in order to approve or deny loan applications, as well as to make pricing decisions. Mortgage default occurs when mortgage borrowers stop making scheduled payments. Consistent with previous work, we define default as having occurred when the borrower falls 3 months behind on his scheduled payments (i.e., the borrower is 90 days delinquent). Prepayment occurs when borrowers prematurely pay off their loans. From a lender's perspective, prepayment can be considered a risk, because borrowers may prematurely pay off their loans when they move or refinance, or when interest rates fall, and the lender does not realize the expected stream of payments in these cases. Default and prepayment each can lead to a loss to lenders, although, given the relative sizes of the losses involved, researchers and practitioners tend to focus more on the risk of default than on the risk of prepayment. If location efficiency influences these risks, it would be beneficial to both lenders and borrowers to understand how location choices affect future mortgage performance. Therefore, it is important to understand the risks inherent in such lending.

There is a large amount of research concerning mortgage risks. One group of studies stresses the importance of the financial benefit of options (Foster & Van Order, 1984; Kau, Keenan, Muller, & Epperson, 1992). This group of studies treats both 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 it becomes beneficial to do so. For instance, borrowers are expected to consider their equity positions in making default decisions: borrowers who owe more to the lender than their houses are worth, net of costs, are expected to be more likely to default than those who have positive equity positions. This theory, although powerful for 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 positions (or options) 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, or a so-called double-trigger framework (Pennington-Cross & Ho, 2010).

Researchers have found empirical evidence supporting the complementary views of the option-based and adverse-trigger-event frameworks. In particular, the current loan-to-value (CLTV) ratio, value of the prepayment option, and local unemployment rate have consistently been found to influence both mortgage default and prepayment. Moreover, certain characteristics of the borrower, the lender, and the servicer have consistent effects. For instance, Quercia, Pennington-Cross, and Tian (2012) confirmed the importance of the CLTV ratio, borrower credit score, borrower income, and unemployment rate in explaining default and prepayment. In this article, we examine the link between mortgage risk and location efficiency, defined in variety of ways. However, we first discuss how location efficiency is determined and why it may be a useful concept in this context.

### **Location Efficiency, Mortgages, and Smart Growth**

Dense urban agglomerations, with a diverse mix of land uses, have been championed as one way to reduce energy consumption and, therefore, decrease the impact of greenhouse gas emissions (Frey, 2003; McLaren, 1992). A recent report by the Transportation Research Board (2009) suggests that, relative to conventional development, channeling most new development to more compact neighborhoods could reduce transportation-related greenhouse gas emissions by 8%–11% by 2050 in the United States. These compact neighborhoods ought to be characterized by access to transit and other amenities. Access to amenities is theorized to provide a better quality of life (Steg & Gifford, 2005), health benefits (Litman, 2015), and wage growth (Roback, 1982).

Transportation costs for an average household in the United States represent about 18% of total household expenditure, which includes an average expenditure of \$2,132 on gasoline and other transportation fuels per annum (Bureau of Labor Statistics, 2013). This spending is commensurate with expenditure on residential energy consumption (Energy Information Administration, 2012). Transportation costs, including vehicle operation and maintenance costs, are the largest costs for a typical household after housing costs. According to Litman (2015), if the households have access to extensive transit options, households spend less (~3 percentage points) on transportation, as compared with households that do not.

In an early study, Holtzclaw, Clear, Dittmar, Goldstein, and Haas (2002) found that automobile ownership decreases with the availability of public transit and neighborhood residential density. Furthermore, they show that the total number of vehicle miles traveled is lower in denser and well-designed neighborhoods that are accessible by public transit. These results were confirmed by Khattak and Rodriguez (2005), who demonstrated that, controlling for self-selection and compared with households in conventional suburbs, households in denser neotraditional neighborhoods, while making a similar number of trips, make shorter trips and are more likely to substitute walking and other nonmotorized modes of transportation for automobile trips. These findings suggest that households experience lower transportation costs when the design, density, and diversity of neighborhoods are suitably modified.

These three Ds are the subject of an extensive transportation literature (Cervero & Kockelman, 1997; Handy, Boarnet, Ewing, & Killingsworth, 2002; Saelens, Sallis, & Frank, 2003). These three aspects of neighborhood form have a significant impact on trip generation, transportation mode choice, and destination choices, all of which impact transportation costs. Locations with high accessibility and many amenities are desirable from the real estate-development standpoint, as evidenced by recent industry reports (e.g., Malizia, 2014).

Based on these ideas, Holtzclaw et al. (2002) proposed that location efficiency be considered part of the mortgage underwriting process. Location efficiency is characterized by low transportation costs that result from high accessibility. The Center for Neighborhood Technology defined *location-efficient communities* to be "dense and vibrant, with walkable streets, access to transit, proximity to jobs, mixed land uses, and concentrations of retail and services."<sup>1</sup> Promoted by the Natural Resources Defense Council and backed by secondary institutions, such as Fannie Mae, these mortgage products allow transportation cost reductions to be factored into debt-to-income ratios (Krizek, 2003c). The rationale for this approach is that the transportation savings of households in location-efficient areas could be put toward the cost of housing.

Alternative mechanisms by which location efficiency may influence mortgage performance include property liquidity and the availability of local employment options. In particular, properties with attractive accessibility amenities may experience a shorter time on the market in the event that the borrower attempts to sell the property. Moreover, borrowers who become unemployed may find it easier to obtain new local employment in areas with a greater nearby diversity or balance of jobs. In such cases, lower rates of default would be observed.

However, the existing literature concerning the attractiveness and efficacy of LEM is mixed. Using proxy measures for transportation energy costs, such as household vehicle ownership, Rauterkus, Thrall, and Hangen (2010) find that transportation energy savings are associated with a lower risk of mortgage delinquency in high-income areas but a higher risk in low-income areas. These results contradict the earlier study by Blackman and Krupnick (2001), who found that the delinquency risk associated with LEM is similar to that of conventional mortgages.<sup>2</sup> In addition, Pivo (2014) found that, for multifamily houses located in areas with high Walk Scores<sup>3</sup> (> 80), the risk of default is 60% lower than in areas with lower Walk Scores, all else being equal. Conversely, in areas with very low Walk Scores (or high automobile dependency), the risk of default is 121% higher. Empirical studies on this and related issues have reached suggestive, inconclusive, and even contradictory findings, in large part because of such studies' reliance on proxy measures and diverse methods of estimating risks.



## **Measuring Accessibility**

Whereas location efficiency can be characterized in many different ways, it is perhaps useful to think about accessibility as a useful proxy. Accessibility in a metropolitan area is primarily a measure of the combination of availability of opportunities and the quality of the transportation/transit networks. Areas with high accessibility are areas that are closer to jobs and other activity centers, such as retail.

Areas with high accessibility are linked to fewer vehicle miles traveled (VMT; Ewing & Cervero, 2010). Using the data from a travel behavior survey conducted in Puget Sound, Washington, Krizek (2003b) argued,

when households relocate and change their [neighborhood accessibility], their travel behavior changes as well, all else being equal. Regression models show that increases in [neighborhood accessibility] result in reduced VMT, reduced [person miles traveled], and reduced number of trips per tour, but an increase in average number of tours. (pp. 278—279)

Thus, increases in accessibility can potentially reduce household transportation costs and can serve as a proxy for location efficiency.

However, there has been some debate about the proper measurement of accessibility. Accessibility is usually constructed either as a cumulative measure of opportunities that are available from a location at a certain distance (or other appropriate metric, such as travel time) or as a weighted measure that is usually based on gravity or a random utility. The relative accessibility of one location with respect to another within a metropolitan area is usually of interest (Dalvi & Martin, 1976), although recent work has also been done to compare relative accessibility across metro areas (Grengs, Levine, Qing Shen, & Qingyun Shen, 2010).

In their wide-ranging review, Geurs and van Wee (2004) suggest that accessibility should account for a land-use component, a transportation component, a temporal component, and a personal component. They suggest that each of these components is indirectly related to the others. In contrast, Mamun, Lownes, Osleeb, and Bertolaccini (2013) use a different approach to account for temporal coverage by using per-capita service frequency and a distance decay factor. In general, however, the temporal accessibility component is ignored, and peak-hour accessibility is measured.

Given the existing diversity of accessibility metrics and their uses, we opted for a portfolio approach to measuring location efficiency by relying on different metrics. We consider four accessibility measures in total, two of which use a gravity formulation and two of which use an entropy approach, to account for the diversity of amenities in a given area (e.g., Krizek, 2003a). The gravity measures are distance-weighted cumulative opportunity measures, whereas the entropy measures of accessibility measure the diversity and mixing of the opportunities in a neighborhood. These different measurement approaches capture different facets of accessibility that may be important for assessing mortgage risks.

The current research is concerned with assessing the mortgage risks associated with location. Specifically, we are interested in assessing whether location, operationalized through accessibility rather than spillovers, affects these risks. Proponents of LEM argue that households that incur lower transportation costs can afford higher housing debt. We examine the validity of this claim in this article by assessing the mortgage risks associated with households living in locations with differential accessibility. If mortgage risks are indeed mitigated, LEM can be redesigned.

## **Research Design and Methods**

Since higher energy costs may reduce households' ability to make mortgage payments, all else being equal, we may find that more efficient locations are associated with reduced mortgage default risks. Households have different transportation needs and patterns, which may partly explain why certain location efficiency measures have not worked well in the previous literature. In this article, we consider employment-based location efficiency measures, because most households will have to commute to work and engage in non-work-based travel despite having heterogeneous tastes in amenities. We test the hypothesis that households living in more efficient locations, as defined by different accessibility measures, exhibit reduced mortgage default risks. To evaluate the effect of location efficiency on the

probability of mortgage default, we estimate a model of loan performance while including a variety of accessibility measures.

Loan performance data typically suffer from censoring. Loan performance data observed at a particular time are not complete unless all borrowers have either defaulted or prepaid. To deal with the problem of right censoring, researchers often use hazard analysis in evaluating mortgage performance. In such an analysis, researchers estimate the conditional event probabilities (i.e., hazards); that is, they estimate the probabilities of default and prepayment, conditional on the loan having survived to each date, as statistically defined. Default and prepayment are considered competing risks because they are mutually exclusive. In the context of this competing-risks model, consider two termination risks: default D and prepayment P. The hazard  $\lambda_i^r(t|X_i(t), \beta_r, \theta_r)$  for individual  $i$ , where risk  $r = D, P$ , given characteristics  $X_i(t)$ , parameters  $\beta_r$ , and unobserved heterogeneity parameter  $\theta_r$ , is defined as follows:

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

With a discrete-time assumption, a multinomial logit model is often used to estimate this equation (see, e.g., Allison, 1984; Kalbfleisch & Prentice, 2002).

We adopt a competing-risks framework for mortgage terminations and estimate the risks of prepayment and mortgage default simultaneously. In particular, we use a multinomial logit model to quantify these risks relative to one another and to test whether the risks posed by CAP mortgages in location-efficient areas differ from those of mortgages in other areas. Formally, the model can be expressed as follows:

$$\ln \left( \frac{\Pr(Y_i = D)}{1 - \Pr(Y_i = D)} \right) = \alpha_D + \gamma'_D X + \tau'_D T + \delta_D C + \varepsilon_D$$

$$\ln \left( \frac{\Pr(Y_i = P)}{1 - \Pr(Y_i = P)} \right) = \alpha_P + \gamma'_P X + \tau'_P T + \delta_P C + \varepsilon_P$$

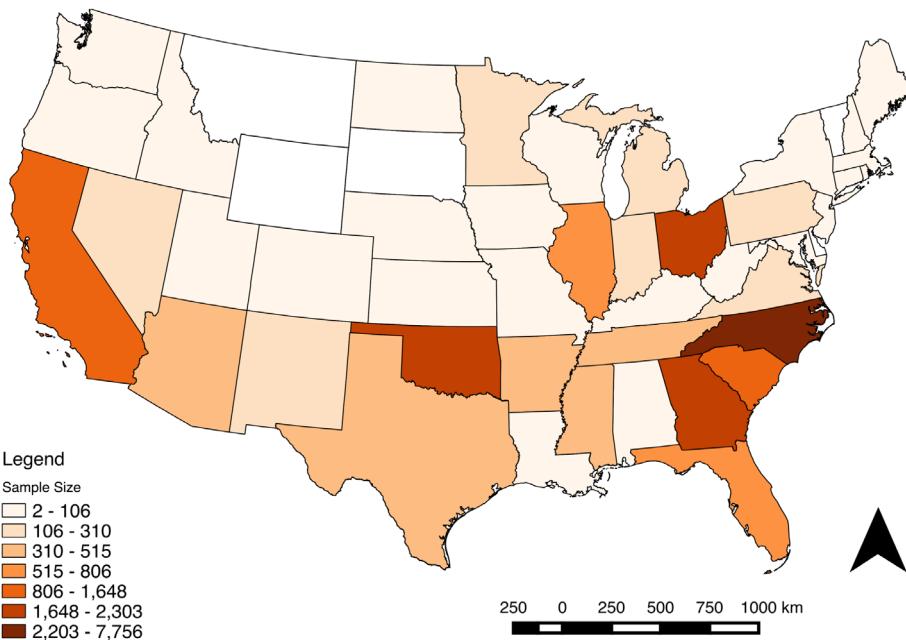
where  $\Pr()$  represents the probability function,  $X$  is the standard set of explanatory variables included in the mortgage termination literature (such as the LTV and the unemployment rate), and  $T$  is a set of dummy variables representing the age of the loan.  $C$  represents the location efficiency measures, and the  $\delta$  are the key parameters to be estimated. This model specification has been used to study mortgage risks in the literature (e.g., Kaza, Quercia, & Tian, 2014; Quercia & Spader, 2008). We describe the different variables used in the models below.

## Data Description

### CAP Data Set

We analyze data from the CAP, which is a targeted secondary mortgage market demonstration program initiated in 1998 by the Ford Foundation, Fannie Mae, and Self-Help, a nonprofit lender with headquarters in Durham, North Carolina. With original underwriting capital provided by the Ford Foundation, Self-Help purchased more than 46,000 qualifying mortgage loans made to low-income households and resold them to Fannie Mae while retaining recourse for a preagreed period of time. Qualifying loans were those made to borrowers who had annual household incomes no greater than 80% of the area median income at the metropolitan level (MSAMI), or who were members of a racial/ethnic minority group or located in high-minority census tracts and had household incomes no greater than 115% of the MSAMI.

As a whole, the CAP loan portfolio comprises predominantly 30-year, fixed-rate loans originated at near-prime interest rates. CAP loans were originated between 1983 and 2014, with more than 80% originated between 1997 and 2007. The median origination LTV ratio for CAP loans was 97%; thus,



**Figure 1.** Sample distribution by state.

the median property value at purchase of \$84,000 corresponds to a median original loan amount of approximately \$79,000. At the time of loan origination, the median CAP borrower was 32 years old, had a household income of about \$31,000, and had a credit score of 681. Approximately 40% of CAP borrowers are members of a racial/ethnic minority group, and about 41% of CAP households were headed by a woman at the time of loan origination. Of the CAP properties 86% are located in urban areas, and about 70% are located in the South, with nearly 33% in North Carolina. As of the end of 2014, approximately 23% of CAP loans remained active, 67% had prepaid, and 7% had ended in foreclosure sale.

Self-Help provided us with comprehensive mortgage origination data and historical payment information for the CAP loan portfolio. These data permit us to track loan performance over time and assess the drivers of both prepayment and default. Moreover, CAP property addresses have been geocoded, which enables us to match the CAP portfolio data with supplemental information from the Federal Housing Finance Administration (FHFA) and the Environmental Protection Agency (EPA). We use the FHFA house price index at the metro level, in combination with the original property value and the outstanding principal balance on the loan, to derive estimates of the CLTV ratio for each mortgage over time. In addition, we use measures from the EPA's Smart Location Database (SLD) at the census block group level to capture the local transit and employment options that are available in the vicinity of each CAP property.

After linking these data sources, we remove observations with missing data and restrict our estimation sample to those properties located in metropolitan areas. Our final sample consists of over 21,000 loans and over 1 million loan observations. Most of these loans are concentrated in North Carolina, Ohio, Georgia, South Carolina, and California. Montana, South Dakota, and Wyoming are completely missing from the sample (see Figure 1).

### **Smart Location Database**

The EPA created the SLD to compare the location efficiency of various places. The SLD summarizes, at the block-group level, various demographic and economic variables, as well as the design of the

built environment and the diversity of land uses and access to destinations (Ramsey & Bell, 2014). Several demographic, employment, and built-environment variables for most census block groups in the United States are available in the data set. These variables have previously been considered in the literature described above and are available for the year 2010. The measures are derived from multiple sources, including the U.S. decennial Census, the American Community Survey, the U.S. Census Bureau's Longitudinal Employment-Housing Dynamics data, and General Transit Feed Specification data. We use four variables from the SLD that measure location efficiency at the block-group level, as described in the next section.

### **Variables Used in the Models**

We include relative income (*Inc\_ami*), which is household income expressed as a fraction of the area median income at loan origination. The monthly mortgage debt payment, normalized by borrower monthly income, or the debt-to-income ratio at origination (*dti*), is included as well as credit score (*fico*) at origination. Income may proxy for the importance of transaction costs, wealth, and education. Therefore, higher income is expected to be associated with lower default probabilities. Higher debt levels at loan origination are associated with higher mortgage default risk. Credit history is expected to be negatively associated with mortgage default risk.

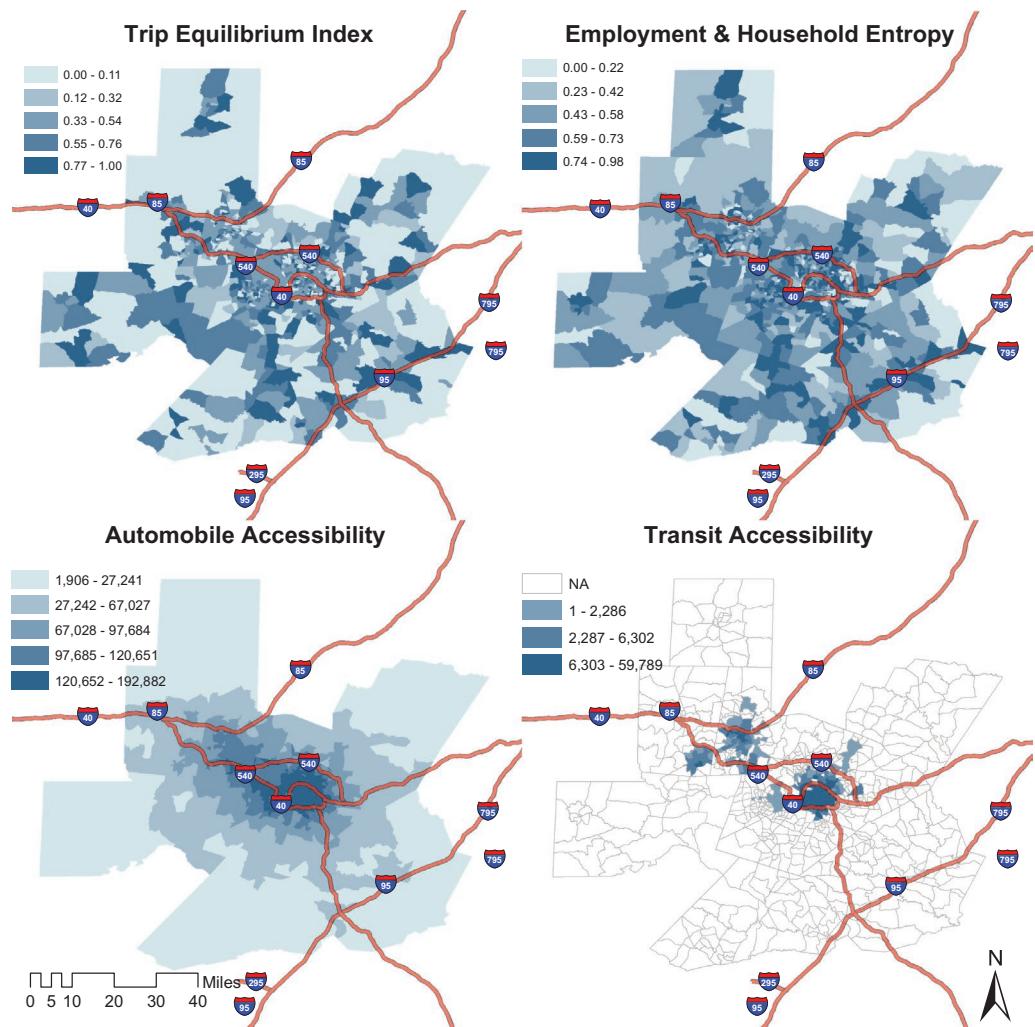
Two variables are included to capture option-theoretic considerations in the joint estimation of default and prepayment risks: the current loan-to-value ratio (*cltv*) and the percentage gain from refinancing (*refi*). A high loan-to-value ratio is expected to be associated with a higher probability of default. We proxy the current loan-to-value ratio using the outstanding balance on the loan and an estimate of current house value calculated using the FHFA's House Price Index at the metropolitan area level. Following the literature, we construct a measure of the net present value to be gained from refinancing a fixed-rate mortgage, which is commonly described as a proxy for the value of the refinance option. The construction of this variable follows previous work by Pennington-Cross and Ho (2010). Empirical results in the literature indicate a positive association between the refinance incentive and mortgage default risk (Pennington-Cross & Ho, 2010).

County unemployment rates (*unempr*) are included to capture labor market conditions. Consistent with prior work, we assume that higher county unemployment rates indicate a higher probability that borrowers have lost their jobs or have lower income streams, both of which make it more difficult to make mortgage payments and may, therefore, increase the probability of mortgage default.

We also include measures of future interest rates and house price volatility, under the assumption that consumer expectations are rational and correctly forecast volatility. Interest rate volatility (*varrate*) is constructed as the moving variance of future eight-quarter, 30-year, fixed-rate conventional mortgage rates, and house price volatility (*varhpi*) is measured as the moving variance of future 2-year metropolitan area house price appreciation. Theory indicates that greater volatility in interest rates and house prices should reduce default probabilities. However, the empirical literature offers no support for these expected results.

In addition, we control for the impact of local foreclosure laws by including in the model the average number of days between the start of foreclosure proceedings and the day when the property is referred for sale (*dsrts*) in each state. Cutts and Merrill (2008) estimate this number using Freddie Mac data. It can serve as a proxy for the amount of free rent that a household can expect to gain during the foreclosure process and the cost of foreclosure that the lender/investor will bear in the event of a foreclosure. Because of the interaction of the lender and borrower, the direction of the impact is an open empirical question.

We operationalize location efficiency using four distinct measures: automobile accessibility, transit accessibility, a trip balance index measuring job–housing balance, and employment housing entropy measured as the diversity of employment and housing in a block group. The first two measures are *regional measures of accessibility*; that is, the location of the block group relative to jobs and transportation networks in the region matters. The second two measures are more local and are calculated for



**Figure 2.** A visualization of the accessibility variables in the Raleigh–Durham–Cary Metropolitan Area, shown as an example of spatial variation.

each block group (see Figure 2). It should be noted that none of these measures is time varying, because of a lack of data availability.

The variable  $D5ar$  is a measure of accessibility by automobile that is weighted by distance and is calculated for each block group  $i$  as follows:

$$\sum_{j=1}^n \text{Emp}_j \cdot (d_{ij}^{0.3}) \cdot \exp(-0.70 \cdot d_{ij})$$

where  $\text{Emp}_j$  is employment in block group  $j$  and  $d_{ij}$  is the travel time between block groups  $i$  and  $j$ . This functional form, along with the associated constants, is widely used in the transportation planning literature (Martin & McGuckin, 1998).

The variable  $D5br$  represents transit accessibility and is calculated similarly, except that  $d_{ij}$  is now the travel time required for transit and walking. Moreover,  $D5br$  is calculated to reflect peak evening travel to account for scheduling variations during the day.

Whereas both  $D5ar$  and  $D5br$  are measures of accessibility, they are not comparable across metropolitan areas. For example, big urban areas have more jobs and, therefore, have block groups with higher accessibility, even when travel times are longer. Transit accessibility depends not only on the spatial distribution of jobs, but also on the availability of transit and headways.

To permit better comparisons across metropolitan areas, we leverage two different measures of *local accessibility* that incorporate the diversity of jobs—the third D of the three Ds concept in the accessibility literature. In particular, we use two metrics that are calculated in slightly different ways but both measure the diversity and balance of jobs and households in a given block group using entropy like measures. See Krizek (2003a) for an explanation and illustration of entropy-based accessibility calculations.

First, the trip balance index ( $D2c\_TripEq$ ) is a weighted indicator of jobs–housing balance and is calculated as follows:

$$\exp \left( - \left| \frac{HH * VT_{hh}}{\sum_i Emp_i * VT_i} - 1 \right| \right)$$

where HH is the number of occupied households in a census block group;  $Emp_i$  is the employment of type  $i^4$ ; and VT is the trip generation rate defined by the Institute of Transportation Engineers for households and employment types. The index is close to 1 when there is a relatively balanced mix of trip attractors and generators within a block group. If the index is close to 0, then the block group is primarily a residential area. If the index is between 0 and 1/e, the block group is primarily an employment zone with very little housing.

Second, the trip mixture indicator ( $D2c\_TrpMx2$ ) captures the relative balance of different types of jobs in the form of entropy and is weighted toward jobs that generate a higher number of trips, such as those in entertainment and services. This measure is calculated as follows:

$$\frac{-1}{\log 5} \left( \frac{HH}{TOTVT} \log \left( \frac{HH * VT_{hh}}{TOTVT} \right) + \sum_i^4 \frac{Emp_i * VT_i}{TOTVT} \cdot \log \left( \frac{Emp_i * VT_i}{TOTVT} \right) \right)$$

where  $TOTVT$  is the total number of vehicle trips generated. If the entropy measure is close to 0, the block group specializes in a particular type of employment or housing. If it is more balanced among various types of employment as well as housing, the index is closer to 1.

Both of these indices are standardized and, hence, can be compared across metropolitan areas. However, the disadvantage of these two measures is that they rely on intrablock-group composition, rather than the location of each block group relative to other destinations. Hence, the accessibility measurements are more local, as compared with the  $D5ar$  and  $D5br$  variables. Summary statistics and expected signs in the models are presented in Table 1.

## Results

This section presents the results of the competing-risks analysis. We expect the correlations among the EPA's location efficiency measures to reduce the explanatory power of these variables if they are all included in the model at the same time. Therefore, we test the effect of each measure in a separate model. Whereas prepayment is estimated simultaneously for each model, we focus our attention on the default models, which are presented in Table 2.

Our empirical specifications include a baseline specification, which is a standard mortgage performance evaluation model without location efficiency measures included, and four specifications each of which includes a different location efficiency measure. Most of our results concerning mortgage default are consistent with the existing literature. The effects of all the loan and borrower characteristics except  $dsrts$ , which measures the foreclosure environment at the state level, are significant. We now consider the results for each variable in turn.

**Table 1.** Variable definitions, statistics, and expected sign.

Variable	Definition	Mean	SD	Expected sign (default)
<i>Inc_ami</i>	Annual income divided by area median income at loan origination.	0.59	0.16	–
<i>dti</i>	The fraction of combined income that goes toward mortgage payments, or the <i>front-end ratio</i> .	0.27	0.07	+
<i>fico</i>	Borrower's credit score at loan origination.	677	64	–
<i>cltv</i>	Current loan amount divided by the estimated house value.	0.80	0.16	+
<i>refi</i>	Percentage reduction in the present value of future payments if the borrower refinances at the market rate. Expressed as a fraction.	0.07	0.08	+
<i>unempr</i>	County-level unemployment rate. Expressed as a percentage.	6.01	2.32	+
<i>varmrate</i>	Variance of future national mortgage rates.	0.000015	0.00001	?
<i>varhpi</i>	Variance of the metro-level house price index of the Federal Housing Finance Agency.	0.000022	0.000034	?
<i>dsrts</i>	At the state level, the average number of days between the start of foreclosure proceedings and the referral of the property for sale.	116.73	59.36	?
<i>D5ar</i>	Number of jobs within a 45-min automobile commute, time-decay (network travel time) weighted.	70,314.77	56,458.92	–
<i>D5br</i>	Jobs within a 45-min transit commute, distance-decay weighted.	1,018.89	3,848.52	–
<i>D2c_TRIPEQ</i>	Trip equilibrium index. Derived by calculating trip productions and trip attractions by CBG; the closer this measure is to 1, the more balanced are the trips at the CBG level.	0.38	0.32	–
<i>D2c_TRPMX2</i>	Employment and household entropy calculations, based on trip productions and trip attractions.	0.53	0.22	–

Note. CBG = census block group. SD = standard deviation.

The impact of relative income is negative and significant, indicating that higher relative income is linked with a reduced likelihood of mortgage default. The effect of the debt-to-income ratio, or front-end ratio, is positive and significant, indicating that a higher default probability is associated with a higher debt level at loan origination. A higher credit score at loan origination is linked with a reduced default probability, since the relevant coefficient is negative and significant. The effect of the current loan-to-value ratio is positive and significant, indicating that a higher current debt level is associated with a higher probability of mortgage default. The effect of the refinance incentive is positive and significant, which is consistent with results previously discussed in the existing literature. The impact of the local unemployment rate is positive and significant, indicating that higher local unemployment is associated with a higher probability of mortgage default. The impacts of the volatilities of the mortgage interest rate and the house price appreciation rate are both positive and significant in our analysis. The only variable that does not have a significant effect is the state foreclosure environment. These results are consistent across the specifications, which suggests that they are robust to the location efficiency measure used.

In the first two location efficiency models, we include the more regional measures of jobs available within a 45-min commute: *D5ar* and *D5br*. These measures are not significant predictors of mortgage default. In the third and fourth models, we include the local accessibility measures *D2c\_TRIPEQ* and *D2c\_TRPMX2*. The impacts of these two variables are negative and significant. Therefore, the loans in neighborhoods with higher local accessibility will have reduced mortgage default probabilities. In other words, when the population in a neighborhood is matched well with employment, there will be less risk of mortgage default. However, the extent to which this risk is reduced is small, as indicated by the odds ratios. Our results support the hypothesis that living in more location-efficient places is associated with reduced mortgage default risk.

It should be noted that the results presented here do not represent evidence of a causal relationship between increased accessibility and a reduction in mortgage risk. Such causal mechanisms should be teased out through a careful research design that would account for endogeneity. However, the

**Table 2.** Default estimates from the competing-risks model.

Specification	Benchmark		Regional accessibility models				Local accessibility models			
			D5ar		D5br		D2c_TRIEQ		D2c_TRPMX2	
	Coefficients	OR	Coefficients	OR	Coefficients	OR	Coefficients	OR	Coefficients	OR
<i>Intercept</i>	-6.636 (0.411)***	-	-6.640 (0.411)***	-	-6.637 (0.411)***	-	-6.637 (0.411)***	-	-6.639 (0.411)***	-
<i>Inc_ami</i>	-0.110 (0.018)***	0.896	-0.110 (0.018)***	0.896	-0.110 (0.018)***	0.896	-0.110 (0.018)***	0.896	-0.109 (0.018)***	0.896
<i>dti</i>	0.040 (0.017)**	1.040	1.038 (0.017)**	1.038	0.039 (0.017)*	1.040	0.040 (0.017)**	1.040	0.040 (0.017)**	1.041
<i>fico</i>	-0.602 (0.016)***	0.547	-0.603 (0.016)***	0.547	-0.603 (0.016)***	0.547	-0.601 (0.016)***	0.548	-0.600 (0.016)***	0.549
<i>cltv</i>	0.305 (0.019)***	1.357	0.305 (0.019)***	1.357	0.306 (0.019)***	1.358	0.305 (0.019)***	1.356	0.303 (0.019)***	1.354
<i>ref</i>	0.190 (0.021)***	1.209	0.191 (0.021)***	1.210	0.190 (0.021)***	1.210	0.190 (0.021)***	1.209	0.190 (0.021)***	1.210
<i>unempr</i>	0.186 (0.018)***	1.205	0.189 (0.019)***	1.208	0.187 (0.018)***	1.205	0.186 (0.018)***	1.205	0.187 (0.018)***	1.205
<i>varmate</i>	0.048 (0.017)***	1.049	0.048 (0.017)***	1.050	0.048 (0.017)***	1.049	0.047 (0.017)***	1.048	0.048 (0.017)***	1.049
<i>varphi</i>	0.068 (0.018)***	1.071	0.070 (0.018)***	1.072	0.069 (0.018)***	1.071	0.069 (0.018)***	1.071	0.069 (0.018)***	1.071
<i>dstrs</i>	-0.002 (0.016)	0.998	0.000 (0.016)	1.000	-0.003 (0.016)	0.997	-0.001 (0.016)	0.999	-0.001 (0.016)	0.999
<i>location_efficiency</i>	-	-	0.024 (0.017)	1.024	0.019 (0.017)	1.019	-0.037 (0.016)	0.963	-0.048 (0.015)***	0.953
# observations	1,081,843		1,081,843		1,081,843		1,081,843		1,081,843	
# loans	21,509		21,509		21,509		21,509		21,509	
$-\log L$	176,051.29		176,049.31		176,048.11		176,024.88		176,021.71	

Note. OR = odds ratios. Standard errors are provided in parentheses. The model is a competing-risks framework that includes mortgage prepayment. The prepayment results are available from the authors upon request. Loan age dummies are included in all models to conform to hazard model requirements. We standardize the continuous covariates to have a mean of 0 and a standard deviation of 1; therefore, the marginal effects reflect the summary statistics provided in Table 1. For example, a marginal change in *fico* in our final model is equivalent to a 64-point change in actual credit score.

\*  $p < .10$ ; \*\*  $p < .05$ ; \*\*\*  $p < .01$ .



results do show that, irrespective of the causal mechanism, the characterization of location efficiency is important. The regional accessibility measures are statistically insignificant, but whereas the local measures are only statistically significant, their substantive significance is relatively low. Increase in one standard deviation in the local accessibility measures decreases the risk of default by 4 percentage points (see Table 2).

## Discussions and Limitations

The transportation costs of a household depend upon the distribution of destinations, the availability of modal options and fuel efficiency, and the costs of various options. Despite the importance of the latter, residential location choice conditions the available modes and destination accessibility. Because household location decisions are sticky and greatly influence transportation costs, it is expected that locations with high accessibility will pose lower risks for mortgage default. These location choices are more salient for low-income households than for average households, as the former are likely to spend a greater fraction of their household budgets on transportation costs.

If a household lives in a location-efficient place, that household has access to a wide variety of amenities and jobs within a short distance and travel time. The reduction in transportation costs may offset any purchase-price premium that location-efficient houses may carry. Advocates of LEM argue that such considerations should affect the standards for credit scores, debt-to-income ratios, and residual incomes that govern loan approvals for potential borrowers. Such adjustments in lending standards would promote greater affordability, especially for low-income households, and are defensible if the mortgages in location-efficient places carry lower risks.

However, our research shows that location-efficiency concessions for low-income borrowers may not be warranted. The regional measures of location efficiency such as automobile and transit accessibility do not have statistically significant impacts in our models. The local measures of location efficiency such as local employment diversity do have statistically significant, but substantively small, impacts on default risks. Because location efficiency is a multidimensional attribute, the research suggests that care should be taken about the choice of the dimensions and their measurement in redesigning the LEM.

The two regional measures of location efficiency studied in this article are automobile accessibility and transit accessibility. Higher automobile accessibility should reduce risks in two different ways. First, the presence of a larger number of jobs within a reasonable commuting distance should mitigate the adverse impact of job loss by reducing transaction costs, such as those associated with job matching. Second, a reduction in transportation costs, especially in the era of higher gasoline prices, should reduce mortgage default risks, because household budgets can be rebalanced. However, we find that no such reduction is obtained for our sample. This result suggests that other factors are much more important predictors of mortgage risks for this population.

The presence of high-quality transit reduces transportation costs. Such a reduction should theoretically change mortgage default risks. However, we do not observe such a change for our sample. We hypothesize that this result may obtain for several reasons. As can be seen from Figure 2, large areas of the United States do not have transit provision, let alone high-quality transit. Many of the captive transit riders, who make up a large portion of all transit commuters, are largely poor and elderly (Krizek & El-Geneidy, 2007). If their housing location choices are dictated by the availability of transit, then the effects of their individual characteristics, such as income and credit score, could easily outweigh any effects of transit provision and quality in explaining default risk.

In addition, we also found that differentiating transit accessibility by fixed-route rail and other modes does not influence our results.<sup>5</sup> This finding is counterintuitive given the existing literature (e.g., Hess & Almeida, 2007), which suggests that rail transit creates a sale premium for households, thereby increasing wealth. This result likely derives from the fact that the sample comes almost exclusively from areas lacking rail transit. Less than 1% (163 loans, or 0.76%) of the loans in the sample actually have any rail stations in their block groups. The lack of rail transit is not surprising, since a large portion of the sample

is located in the South, which is not known for its rail transit (see Figure 1). A sample of mortgages with more loans in rail transit-rich areas might provide different results. Exploring this possibility is left for future work.

The four accessibility measures we chose capture two different dimensions of accessibility: destinations and diversity. The regional accessibility measures are the measures of destination accessibility, whereas the local accessibility measures are measures of diversity. The results suggest no discernable impact of destination distributions but a significant (if small) impact of local diversity of uses. There are other metrics that are important predictors of travel demand, notably density and design. Preliminary analyses with this sample showed that density is not associated with mortgage risks. It could also very well be that design characteristics impact travel behavior modestly (Cervero & Kockelman, 1997; Crane, 2000). Because design variables are not consistently measured and are not universally available, we are unable to model their impact on mortgage risks. Further research could pursue these lines of inquiry and validate the results.

This research uses neighborhood-level characteristics because they are used to design and implement programs accounting for the location efficiency of mortgages. However, such interpretation is subject to the ecological fallacy. Further research is needed to uncover direct links among transportation behavior and choices, including daily VMT, modes, destination choices, and mortgage risks. Data sets that capture both mortgage performance and travel behavior are unavailable. Household travel surveys could be expanded to capture household consumption patterns and link them directly to mortgage information; such a linked data set would permit more definitive conclusions to be drawn about causal relationships. With the advent of pay-as-you-drive insurance policies and mileage-based taxes, it will be possible to monitor household travel behavior and expenses accurately (subject to privacy concerns). These programs could make it easier to measure the causal links between household transportation spending and mortgage risks.

Furthermore, this research indicates that location efficiency is a complicated construct with different dimensions that operate on different scales. We show that regional accessibility is not associated with mortgage risks but that local accessibility is. The regional accessibility measures are not scaled to account for intermetropolitan differences, whereas the local measures are. For example, it is possible that households living on the outskirts of a metropolitan area with a large economy will have higher regional accessibility than those within the central cities of a smaller metropolitan area. Any design of newer LEM should account for these different dimensions. It could also very well be that local neighborhood characteristics that are captured by the location efficiency variables might be salient for mortgage risks rather than location within the regional metropolitan areas.

## Conclusions

In recent years, proponents of sustainable urban development practices have promoted the creation of compact cities (Burton, Jenks, & Williams, 2003). This goal can be realized in part by incentivizing urban infill development and disincentivizing greenfield development. Since urban infill development occurs in areas that are already served by the existing automobile and transit infrastructure, considering location efficiency in mortgage underwriting could mitigate the impacts of the sprawl that has characterized postwar urban development in the United States. We find that the local neighborhood diversity measures are statistically significant but substantively small predictors of mortgage risk. The more varied uses (residences and jobs) are present in the block group, the lower the default risk. If different employment categories are represented in a given block group, then default risks in that block group are slightly lower. Whether this decrease is due to the presence of different amenities nearby that reduce transportation costs, and whether such amenities afford steadier employment opportunities, are unresolved questions that require further research.

Overall, LEM have not been successful, and this study provides some insight into the drivers of the underlying mortgage risks. Chatman and Voorhoeve (2010) put it succinctly:

First, there may still be little market for [LEM] because it may enable only a marginal difference in buying ability. Second, it may not increase transit ridership because it may largely fail to target transit-using households. Third, even if there is market demand for development in location-efficient neighborhoods, it may not result in more transit users and walkers living in location-efficient neighborhoods or more housing supply in those areas because of local regulations on development. (p. 372)

The key takeaway from this and earlier research is that the design of the LEM should be carefully rethought. Whereas transportation costs represent a large portion of household expenditures and are closely tied to the location of the house, this research indicates that different measures of accessibility have different impacts on the underlying mortgage risks of low-income residents. The local accessibility measures matter more than the regional ones, and they should be taken into account in redesigning LEM.

## Notes

1. (<http://www.cnt.org/projects/location-efficiency-hub>)
2. This study is limited to Federal Housing Administration (FHA) loans in Chicago, Illinois.
3. A higher Walk Score indicates more pedestrian accessibility characterized by pedestrian amenities and short distances to destinations. The score is scaled from 0 to 100.
4. The four employment types are retail, office, service, and entertainment.
5. Results are not shown, but are available from the authors upon request.

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No potential conflict of interest was reported by the authors.

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