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The Contagion Effect of Neighboring Foreclosures†

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We examine the contagion effect of residential foreclosures and find strong evidence of a social interactions influence on default decisions where the interaction is based on neighbors' behavior in a previous period. Using a unique spatially explicit parcel-level dataset documenting residential foreclosures in Maryland for the years 2006–2009 and a highly localized neighborhood definition, based on 13 nearest neighbors, we find that a neighbor in foreclosure increases the hazard of additional defaults by 18 percent. This feedback effect goes beyond a temporary reduction in local house prices and implies a negative social multiplier effect of foreclosures. (*JEL* R23, R31)

There is no question the United States has endured a dramatic period of foreclosure activity between 2007 and 2010 that has been unlike any period in recent decades. National foreclosure starts increased from 1.5 million in 2007 to 2.8 million in 2009, and the share of mortgage loans that were seriously delinquent reached 5.2 percent by the third quarter of 2008, compared to the 1979–2006 average of 1.7 percent and the previous high of 2.7 percent in 2002 (Mayer, Pence, and Sherlund 2009). This period of increased foreclosure activity has introduced new phrases into the public lexicon, most notably for this work, the notion of "strategic default," which occurs when those who can afford to pay make the strategic choice to walk away from their mortgage. Anecdotal evidence suggests that strategic defaults are becoming more common and more socially acceptable.[1]

Recent academic research has established that foreclosures within a neighborhood have a significant and highly localized feedback effect on house prices in the neighborhood (see Frame 2010 for a survey of this literature). Harding, Rosenblatt, and Yao (2009) find a peak contagion effect of nearby foreclosures on house prices of approximately 1 percent. Campbell, Giglio, and Pathak (2011) find that local foreclosures reduce nearby house prices. Their preferred estimate suggests that

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[1] For examples, see Lowenstein, Roger, "Walk Away from Your Mortgage!" *New York Times*, January 7, 2010, accessed July 22, 2010, http://www.nytimes.com/201%1/10/magazine/10FOB-wwln-t.html; Streitfeld, David, "Biggest Defaulters on Mortgages Are the Rich," *New York Times*, July 8, 2010, accessed July 22, 2010, http://www.nytimes.com/201%7/09/business/economy/09rich.html; "Strategic Default: Walking Away from Mortgages," *60 Minutes*, May 10, 2010, accessed July 22, 2010, http://www.cbsnews.com/8301-18560_162-6466484.html.

within a distance of 0.05 miles, neighborhood foreclosures reduce house prices by approximately 1 percent. The potential that foreclosures may cause house price declines, which stimulate further foreclosures, is cited as a motivation for plans implemented by the Obama administration (Campbell, Giglio, and Pathak 2011). This line of research presents strong evidence that local foreclosures do impact local house prices, but it does not establish a link between foreclosures and subsequent defaults by nearby homeowners.

What differentiates the current foreclosure period from foreclosures in the recent past is the potential for non-price spillover effects (Lowenstein 2010). Using survey data derived from hypothetical questions, Guiso, Sapienza, and Zingales (forthcoming) examine the potential importance of social interactions on the propensity to default on home loans. They find evidence that an individual who observes someone in foreclosure is more likely to state they will default, and that homeowners experiencing a steep equity decline state that they would feel less of a moral obligation to repay their lender. These results suggest that foreclosures in concentrated areas may be an outcome of a contagion effect driven by a reduction in the moral/social constraints on foreclosure, deteriorating expectations about the future trajectory of local neighborhoods, or the price declines identified in the previous literature.

In this paper, we examine a highly localized contagion effect of foreclosures and find strong evidence that social interactions influence the decision to default by homeowners who observe a nearby neighbor in foreclosure. We utilize a hazard model and a unique spatially explicit dataset documenting parcel level residential foreclosures in Maryland for the years 2006 through 2009. We combine these data with tax and assessment data, loan data, and census and unemployment data. These data allow us to control for important factors influencing the likelihood of foreclosure within a given community, including the prevalence of subprime loans and the distribution of socioeconomic characteristics. Additionally, we use the tax data to construct variables describing individual homes, surrounding homes, and the community. These variables include structural characteristics of houses, their price history, occupancy status, neighborhood stability during the boom years, and length of ownership.

We are able, in this study, to overcome a number of identification issues common to empirical analyses of social interactions. First, to avoid issues of simultaneity that often hinder identification of social interactions in empirical studies, we take advantage of the panel nature of our data. Specifically, as outlined in Manski (2000) and Brock and Durlauf (2001), we use lagged values of the social interaction variable to overcome the reflection problem typically encountered in social interaction models. We identify the role of social interactions using a time varying measure of the mean number of neighboring foreclosures. We expect that observing neighbors who default and are foreclosed upon by their lenders increases the likelihood of default by nearby homeowners through the price-depressing impact of neighboring foreclosures, the impact of neighboring foreclosures on households perception of the future trajectory of their neighborhood, and by reducing the moral or social constraints associated with foreclosure. Each of these impacts is a classic endogenous interaction in the Manski, framework. However, as we argue below, it is unlikely that price impacts of the magnitudes found in the existing literature—notable studies

include Immergluck and Smith (2006); Harding, Rosenblatt, and Yao (2009); and Campbell, Giglio, and Pathak (2011)—are a significant cause of subsequent defaults by neighbors.[2]

A second general concern in social interaction models is choice of group and group size. The previous literature examining the price spillover effects of neighboring foreclosures has used spatial buffers to define reference group membership. This method of defining group size in urban areas of differing densities is problematic for identification and may simply be picking up spurious correlation. We have been able to avoid this problem by defining "neighbor" as the nearest 13 and nearest 25 neighbors by distance. This measure of neighborhood is sufficiently small that spurious correlation among loosely related neighbors should be minimized as an econometric issue. Additionally, this definition of social group is purposely limited to the dimension of housing proximity and thus interaction probability as in Bertrand, Luttmer, and Mullainathan (2000). Our group definition should therefore be viewed as a minimal measure of the social groups to which any household may belong. For example, we exclude non-proximity based groups such as employment, ethnicity, gender, education, friends, and family.

Our study area, Maryland, provides a good opportunity to study endogenous interactions as they relate to residential foreclosures. The state experienced an increase in foreclosures similar to the national increase in the foreclosure rate. At the same time, Maryland was subjected to less severe forms of the typical economic causes of foreclosure, which most commonly have been house price collapse and job loss. The state did not experience a severe shock to employment as it is buffered from dramatic job losses by the prevalence of Federal jobs and contracts. The state also did not experience as large a house price collapse as was experienced in the high foreclosure states of Arizona, California, Florida, and Nevada. Nationally, we've seen that noneconomic factors including the social stigma associated with foreclosure, a change in the moral constraints on foreclosure that may occur due to high foreclosure activity, and changes in the perceived impact of foreclosure on a household's credit rating can also have a significant impact on foreclosure rates. Given the relatively smaller shocks to employment and house prices in Maryland, we expect these factors to have a larger impact on foreclosures in the state than in some of the higher foreclosure areas of the country.

Our definition of a contagion effect is consistent with the view that negative equity is a necessary condition for default. We control for house price expectations using a local repeat sales price index, as well as including a variable that measures the extent to which the sales index has fallen relative to its peak value. In addition to house price depreciation, increased originations of subprime loans coincide with an increase in foreclosures (Meyer, Pence, and Sherlund 2009). We find strong evidence that a greater prevalence of subprime loans increases the likelihood of household foreclosures as does a subpar stock of housing. In addition, we find that homes with longer ownership tenures, and homes in established communities with fewer rentals, are less likely to go into foreclosure.

[2] A point especially relevant for our study period and area which, in contrast to other communities in the United States, has not experienced a steep decline in home prices.

Most significantly, we find strong evidence that endogenous interactions influence the decision to default. Using our highly localized neighborhood measure, we find that a one-unit increase in neighboring foreclosures increases the hazard of foreclosure by 18 percent. This result is highly statistically significant, and suggests that foreclosures influence the likelihood of future defaults and foreclosures in their immediate neighborhoods. This feedback effect goes beyond a contagion due to a temporary reduction in local house prices and implies a social multiplier effect as societal attitudes toward foreclosure become less negative and households' expectations about the future of their neighborhood changes. Our most conservative estimate of an 18 percent increase in the hazard rate controls for correlated unobservables using fixed effects at the very disaggregate census block group level which is important within the social interactions framework. Our results are robust to alternative definitions of neighborhood and alternative classifications of the number of neighboring distressed properties. We also show that the estimated contagion effect increases as we use more aggregated geographic controls for correlated unobservables.

In the remainder of the paper, we examine the contagion effect of residential foreclosures. Section I outlines social interactions as they relate to residential home loan defaults. Section II presents the duration models used in the analysis, followed by a background of the study area in Section III. The data used in the study and selection of variables are presented in Section IV. Section V presents results, starting with main results followed by an assessment of the robustness of the main results. The last section provides concluding remarks.

I. Social Interactions and Home Loan Defaults

There is extensive literature on social interactions in economic decision making (Manski 1995). Three factors may result in members of the same group behaving similarly: correlated effects, contextual interactions, and endogenous interactions. Correlated effects occur when individuals with similar individual characteristics, preferences, or institutional environments act in a similar manner. Contextual interactions occur when the behavior of an individual group member is influenced by exogenous events or exogenous characteristics of other group members. We are interested in identifying endogenous interactions—the actions of others causing members of a group to act in a similar manner—in residential foreclosure decisions. Endogenous interactions are of most interest in this study because their presence implies homeowners alter behavior in response to the observed behavior of their neighbors.

Manski (2000) identifies three economic processes within endogenous interactions: constraint, expectation, and preference interactions. Constraint interactions arise when the actions of one agent influence the feasible set of options available to another agent; congestion or publicly available knowledge from research and development are examples. Expectation interactions are generated by observational learning, wherein agents form expectations based on observed actions and choices of others. Finally, endogenous interactions may occur when an agent's preferences are influenced by the actions or choices made by members of the individual's reference group. Preference interactions might result from conformism, stigma, or other social influences.

In the context of residential foreclosures, much of the research effort to date has focused on the price-depressing effect of neighboring foreclosures—a constraint interaction. Foreclosures increase the supply of houses on the market, and decreased upkeep of the foreclosed homes deteriorates the visual appeal of the neighborhood to potential buyers. This reduces the value of surrounding houses, altering the equity position of these households. Previous research indicates that the price-depressing effect of local foreclosures is relatively small (Harding, Rosenblatt, and Yao 2009; Campbell, Giglio, and Pathak 2011). The emerging consensus suggests that a neighboring foreclosure's price-depressing effect amounts to approximately 1 percent of house value. It therefore seems unlikely that one would observe contagion in mortgage defaults based on the relatively small losses in equity induced by neighboring foreclosure activity. In our study area, we do observe distressed properties disproportionately locating around previously foreclosed properties and to attribute this very non-marginal decision to marginal price declines alone seems implausible.

In addition to constraint interactions, the non-price *preference* and *expectation* interactions due to neighboring foreclosures might be an important cause of contagion in foreclosures. Without question, strong moral and social constraints on foreclosure have the effect of preventing households from entering into default when it is in their financial interest to do so. Households' willingness to default is influenced by the possibility of social stigma and the constraint of moral norms that suggest foreclosure is to be avoided, even at significant financial cost.[3] Further, observing neighboring households in foreclosures may alter expectations about the future trajectory of the neighborhood. In other words, observing a large number of neighbors in foreclosure may send a signal that the neighborhood is declining and will be less likely to rebound once the foreclosure crisis has passed. The extent to which endogenous preference and expectation interactions influence foreclosure is dependent on the extent to which each homeowner considers foreclosure an option. As suggested by the preliminary work of Guiso, Sapienza, and Zingales (forthcoming), observing others in foreclosure is an important driver when considering the option yourself.

II. The Model

Following Brock and Durlauf (2001), and similar to Sirakaya (2006), we model social interactions as affecting the likelihood of transition from one state to another. In our case, social interactions influence the probability of an individual household defaulting on its mortgage and going into foreclosure. Let T denote the year the foreclosure occurs, or equivalently, the duration from $t = 0$ that the household is not foreclosed on.[4] The individual foreclosure hazard function for household h at time t with covariate vector z_h is written as

$$\lambda(t, z_h) = \lambda_0(t) \exp(\theta' z_h), \tag{1}$$

[3] Guiso, Sapienza, and Zingales (forthcoming) present survey evidence that the social and moral constraints loosen as the number of foreclosures in a household's neighborhood increases.

[4] Maryland has in place legal time limits by which the foreclosure process must proceed making the full filing to sale time window last an average of 18 months. In short, there is no reason to believe a lender will delay filing a foreclosure notice as soon as the legal default period is complete.

where $\lambda_0(t)$ is the baseline hazard and θ is a vector of unknown parameters.

Equation (1) ignores the possibility of time varying covariates for ease of exposition. Including them amounts to adding "spells" to the data, where a "spell" is defined as an interval of time and the associated quantities relevant to each observation during that interval. That is, an observation will contribute multiple spells of data, one for each time interval over which the covariates remain constant. Our data contain time varying covariates.

To formalize the model, let us denote the neighborhood of each household using n. Ioannides (2002, 2003) establishes the importance of endogenous interactions in residential neighborhoods, demonstrating that homeowners' valuations of their own homes depend on the valuations of their immediate neighbors, and that maintenance decisions depend on the level of maintenance taken on by immediate neighbors.[5] In this paper, each household's immediate neighborhood is comprised of its nearest 13 and nearest 25 neighbors.

The probability of default for household h depends on household characteristics, x_h; characteristics of the households community, y_c; and the default and foreclosure behavior of neighborhood households, $m_{n(h)}$, which denotes the number of neighborhood households in foreclosure by time τ. Given these elements of the covariate vector z_h, the hazard model can be rewritten as

$$\lambda(t, x_h, y_c, m_{n(h)}) = \lambda_0(t) \exp(\alpha' x_h + \beta' y_c + \varphi' m_{n(h)}), \tag{2}$$

where α, β, and φ are vectors of unknown parameters.

There are important explicit assumptions involved in estimating a traditional hazard model, most noticeably the choice of baseline hazard specification. Since there is no a priori reason to suspect any shape of the baseline hazard based on institutional knowledge or past experience it is probably most appropriate to utilize either a semiparametric proportional hazard specification, which allows the baseline hazard to take any shape without restriction between periods, or a Cox proportional hazard model where the baseline hazard function is not specified. We estimate a series of piecewise exponential hazard models and Cox proportional hazard models.

It is well documented that identification is an issue in interactions models because the group versus individual influences are likely correlated (Brock and Durlauf 2001). Use of a hazard model addresses the reflection problem discussed by Manski (2000); the data are collected in a panel, permitting specification of the likelihood of default and foreclosure as a function of neighboring foreclosures occurring recently but not contemporaneously. A similar approach is used by Sirakaya (2006) to examine the role of social interaction effects in recidivism rates among probationers. In the Sirakaya (2006) framework, probationers are needed to form expectations on the recidivism activity of other probationers in the neighborhood. In contrast, the actors in our model directly observe evidence of a neighbor's foreclosure decision through

[5] In Ioannides (2002, 2003), the immediate neighborhood includes the nearest ten neighbors.

a number of potential channels, including the tendency of foreclosed properties to fall into disrepair, or simply personal knowledge of the neighbor or the neighbor's situation.

III. Study Area and Background

Maryland provides a unique opportunity to study the endogenous interaction effects of residential foreclosures. Consistent with the national experience, Maryland experienced a sharp increase in foreclosures starting in 2007. Our study area includes the contiguous block of counties in Maryland from the suburbs of Washington, DC to the suburbs of Baltimore as shown in Figure 1. These counties, including Prince George's County, Montgomery County, Anne Arundel County, and Baltimore County accounted for the majority of foreclosure activity in Maryland.

One of the primary drivers of many traditional home loan default decisions is job loss. In Maryland, the federal government acts as a firewall that protects the region from the full brunt of economic downturns, as it has in this most recent period of high national unemployment. For example, as of the middle of 2009 the Bureau of Labor Statistics reports that the unemployment rate in Maryland is 15th lowest in the nation, and the year-over-year increase in the unemployment rate is 7th lowest. The counties in our study area all rank in the bottom third in unemployment rate, between 5.4 and 7.7. However, over the same time interval Maryland ranks 12th in the nation in foreclosure rate, according to Realty Trac (DHCD 2009). In short, Maryland is at or near the lowest quartile in unemployment statistics while being near the highest quintile in foreclosure activity.

This relates to our social interactions research because, although we do not directly observe job loss at a household level, we assume the spatial distribution of job loss is random within a county, census tract, block group, or block, depending on the model. Given the large and diverse labor market in this metro area, including the downside buffer provided by the federal government, one would not expect to find highly localized spatial pockets of job loss in this part of Maryland as one might expect in a less diverse or more vulnerable labor market such as Las Vegas, Phoenix, Florida, or areas of California where foreclosures have been highest and local employment rates have declined rapidly. In other words, in our study area, a mass layoff event at one factory or in one highly specialized sector will not affect one suburban block of homes disproportionately more than any other suburban block of homes in the same census area.[6]

Nationally, foreclosures tended to be driven by the dramatic fall in house prices due to bursting of the house-price bubble. Although variation in the house price boom was highly spatially varied, Glaeser, Gottlieb, and Gyourko (2010) estimate the extent of the increase is potentially as high as 46 percent in real terms between 2001 and 2005. The national fall in house prices from their peak in July 2006 was at least one-third by April 2009, and remained above one-fourth through August 2010

[6]The suburban block is a reasonable description of the 13 nearest neighbors for a vast majority of our dataset.

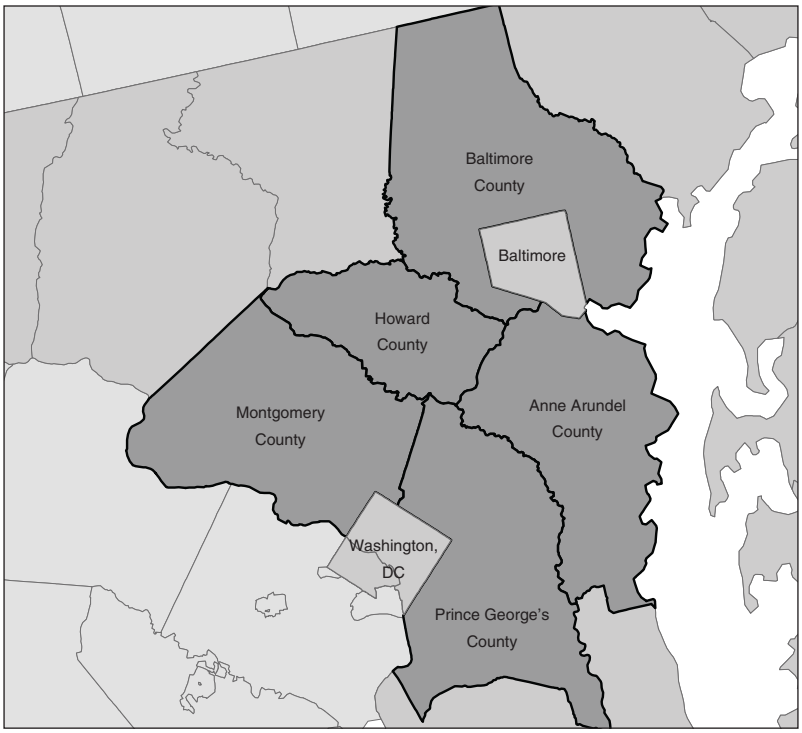

FIGURE 1. MAP OF STUDY AREA

(S&P/Case-Shiller Home Price Indices). The experience in the Washington, DC metropolitan area was consistent with the national decline in house prices. As of December 2009, the Case-Shiller Home Price Index decreased by 29 percent as compared to the peak of house prices in Washington, DC in March 2006. The Maryland study area therefore experienced an average house price decline. This implies our results are not driven by a localized collapse in house prices as was experienced in the high foreclosure states of Arizona, California, Florida, and Nevada. If the spatial distribution of foreclosure activity in these counties of Maryland is likely not driven by job loss and the extent of the price decline is near the national average, then endogenous interactions may be playing a significant role in the relatively high foreclosure rates in the study area.[7]

IV. Data and Variable Selection

The primary data source for this study comes from county level tax and assessment data from each county in the state of Maryland updated monthly via Maryland's Department of Planning and packaged yearly in a data product called Maryland

[7] Though Maryland is a recourse state, the lender has only three years to seek recourse and, to date, no lender has sought recourse. While not a sufficient condition for strategic default, the fact that lenders are unlikely to seek recourse is a necessary condition for strategic default to be worthwhile.

Property View (MPV). We have combined this data with the Home Mortgage Disclosure Act (HMDA) data for loan attributes including socioeconomic characteristics of applicants, and most importantly we utilize an address level dataset of foreclosure activity from the Maryland Department of Housing and Community Development. Much, if not all, of the previous research has relied on more aggregate measures of foreclosure activity. In the analysis we include variables controlling for contextual interactions and correlated effects in order to isolate the influence of endogenous interactions on foreclosures. Summary statistics are provided in Table 1.

Endogenous Interactions.—Our primary measure of the endogenous interaction variable is constructed based on the number of neighbors among the nearest 13 or 25 that are distressed properties, updated quarterly through the sample period of 2006 through 2009. Our data allow us to identify all default notices[8] as well as all parcels that have completed foreclosure as of January 2011. In Maryland, the act of being in default requires a homeowner to be three months delinquent on their mortgage and we classify these homeowners as *distressed*. We define $m_{n(h)}$ using 13 and 25 nearest neighbors to provide a robustness check on the definition of neighborhood.

We construct two subclasses of distressed homeowners for this analysis. The first subclassification—*all distressed*—includes as a "failure" event in the duration model any home that receives a default notice whether they complete foreclosure or not by January 2011. The second subclassification—*completed foreclosures*—includes as a "failure" event in the duration model any home that receives a default notice and that ultimately completed the foreclosure process. We expect the true endogenous interaction impact likely lies in between these classifications as both these classifications miss relevant details. The latter classification undercounts short sales while the former classification over counts failure events in the case where the homeowner subsequently pays the mortgage to current status, the home never falls into disrepair, and the community is not aware of the distress on these homeowners. Short sales are not uncommon in this area and it is currently unclear to what extent homeowners have been able to "work out" a repayment schedule or loan modification to remain in their homes.

All endogenous interactions measurements are made using neighboring parcels that have received a default notice and ultimately complete the foreclosure process. Thus, the endogenous interactions are intentionally limited to parcels most likely to either be vacant or in a state of disrepair or limited maintenance. By our measure, a neighbor may short sell a distressed property and thus will not be included as a surrounding foreclosure event for either subclassification, but may carry an endogenous interaction effect similar to a foreclosure. On the other hand, a distressed property that may be removed from its distressed state by paying the past due amounts will never be included in the model as an endogenous interaction because these instances have little potential to influence neighbors' behavior. Our main results are based on the *all distressed* subclassification. We also present results

[8] Occasionally, the timing corresponds to the Appointment of Substitute Trustee filing in the court records which indicates the lender has begun the necessary process to retake possession of a property.

Table 1—Summary Statistics

Variable	Mean	SD	Min	Max
Endogenous interaction				
Number of neighboring foreclosures 13 NN	0.164	0.446	0	9
Number of neighboring foreclosures 25 NN	0.321	0.672	0	11
Household characteristics				
Owner-occupied	0.816	0.387	0	1
Current owner's tenure, less than 5 years	0.521	0.500	0	1
Current owner's tenure, 5 to 15 years	0.281	0.449	0	1
Current owner's tenure, 15 to 30 years	0.155	0.362	0	1
Age of home, less than 5 years	0.054	0.226	0	1
Age of home, 5 to 15 years	0.133	0.339	0	1
Age of home, 15 to 30 years	0.247	0.431	0	1
Condo	0.117	0.321	0	1
Townhouse	0.042	0.201	0	1
Low-quality house construction	0.402	0.490	0	1
Good-quality house construction	0.094	0.292	0	1
Very good quality house construction	0.023	0.150	0	1
Travel time to Baltimore (minutes)	40.14	16.03	0	81.66
Travel time to Annapolis	48.55	15.14	0	97.16
Travel time to Washington, DC	37.14	16.44	0	100.22
Neighborhood and community characteristics				
Median income	50,932	15,554	0	150,001
Percent minority	29.11	26.18	0	100
Median rent	724.35	180.38	0	1001
Percent with college education	59.11	17.03	0	100
Percent below poverty	4.18	3.64	0	96
Population density	23.68	34.30	0	2,486.43
Percentage of owner-occupied housing in 500-meter buffer	61.46	32.51	0	100
25th percentile tenure of residents in 500-meter buffer	2.211	1.725	0	55
50th percentile tenure of residents in 500-meter buffer	5.64	3.70	0	66
75th percentile tenure of residents in 500-meter buffer	12.17	7.54	0	66
Median age of residential properties in 500-meter buffer	26.89	20.50	0	283
Ratio of multifamily to total buildings in 500-meter buffer	13.40	24.97	0	99.84
Ratio of commercial to total buildings in 500-meter buffer	4.87	6.70	0	100
Average turnover of property in block last 5 years	5.70	2.58	0	33.33
Loan characteristics				
Ratio of conventional loan to average sales value by tract	72.43	20.85	0	1,676.51
Ratio of refinance loan to average sales value by tract	72.88	20.70	0	668.55
Ratio of conventional loan to average assessed value by tract	125.02	45.75	0	3,228.46
Ratio of refinance loan to average assessed value by tract	124.93	41.60	0	1,075.93
Applicant income for refinance applications	102.23	40.58	0	583.57
Applicant income for conventional loan applications	114.89	46.81	0	550.33
Loan for refinance applications	268.29	109.35	0	3,177.27
Loan for conventional applications	271.92	116.69	0	5,028.25
Minority share of loans	41.34	28.56	0	94.65
Subprime share of loans	17.72	9.94	0	49.89
House price and unemployment				
Repeat sales price index	130.12	27.85	53.6	269.73
Percent of most recent price index off the peak value	5.34	9.95	0	59.61
Ratio of average sales value to average assessed value by tract	1.73	0.42	0	8.27
Average sales value by tract	392.95	195	0	1,759.24
Assessed value	241.94	176.11	50.4	3,461.90
Average of 12-month unemployment rate	4.13	1.37	2.5	10.16
Standard deviation of previous 12-month unemployment rate	0.142	0.134	0.04	0.909
Observations		1,071,786		

for the *completed foreclosure* subclassification and show that the results are robust across these classifications.

Household Characteristics.—We include a number of household-level characteristics representing correlated effects. Measures of the quality of house construction broken down into four categories—low, average, good, and very good (where average is omitted from the model)—are used as a proxy for the quality and indirectly the value of the house, which should be correlated with the income and wealth of the household. Two-fifths of the houses in our sample are considered low quality, roughly half are average quality, and just over 10 percent are rated as good or very good quality. We also control for travel time to major cities including Baltimore, Annapolis, and Washington, DC (Mishra et al. 2011).

We control for owner-occupancy with a dummy variable equal to one if the household is owner-occupied. Gerardi and Willen (2009) find that owner-occupied houses are less likely to go into foreclosure. Since the costs of foreclosure are higher for owner-occupied houses due to relocation costs and the likely but unobservable sentimental attachment to community, we also expect owner-occupied houses in this study to be less likely to go into foreclosure. The age of the house is included to control for the vintage of construction as well as proxy for the equity position of the homeowner. We expect newly constructed houses to have larger outstanding mortgages and as a consequence, owners of newly constructed homes are more likely to be in negative equity positions due to recent price depreciation. We include three dummy variables indicating age of the house. The first takes a value of one if the house is less than five years old, the second takes a value of one if the house is between 5 and 15 years old, and the third takes a value of one if the house is between 15 and 30 years old. Homes older than 30 years are the omitted category.

The length of the current ownership tenure is expected to be positively correlated with attachment to community and potential stigma due to default as well as proxy for homeowners most susceptible to the recent decline in prices. Though the current ownership tenure may be correlated with lower outstanding mortgages we cannot say with certainty because there may be large second mortgages on homes with relatively long ownership tenures.[9] Examining foreclosures on a case by case basis proves this is often the case in our study area. On average one would expect longer current tenure to reduce the likelihood of foreclosure. As with age of house, we include three dummy variables indicating the length of the current tenure, including less than five years, between 5 and 15 years, and between 15 and 30 years. Current tenure length in excess of 30 years is the omitted category.

Finally, we observe whether or not the property is a multifamily home, which can be further broken down into condo and townhouse. Previous studies have shown that multifamily properties are more likely to foreclose (Gerardi, Shapiro, and Willen 2009; Foote, Gerardi, and Willen 2008). We do not have strong a priori expectations for multifamily properties in Maryland as the unfolding of this crisis

[9] Ideally we would control for loan age, which would better capture borrowers that originated loans when house prices were at their peak. Unfortunately, we do not observe the loan age for individual households and instead rely on age of house and tenure in current house.

does not have a peer in recent memory and we are studying a suburban area with relatively few condo properties (roughly 12 percent) and often these condo properties are occupied by fixed income retirees.

Neighborhood and Community Characteristics.—We control for a significant number of potential contextual interactions using sociodemographic indicators at the census tract and block-group levels. Median income, median rent, percentage of college educated, percentage below the poverty line, and percent minority population are used from the 2000 census at the tract level. We also include loan applicants' income for both existing residents and new residents and the percentage of purchased loan applications from minority populations from the HMDA data, which are a more current snapshot of new and current loan seeking residents of these areas. These data are calculated as two year moving averages and are updated each year. Population density at the block level controls for the extent of urbanization in the community. As a control for the stability of the neighborhood and since property "flipping" came into vogue during the years leading up to this crisis, we include a variable for the average turnover rate in residential properties over the past five years (measured at the census block level) to proxy for how this past activity might influence current foreclosures. Areas with higher turnover rates are likely areas of speculation in housing price appreciation and thus we expect this to positively impact foreclosure rates.

As required for empirical identification, a number of variables are measured at the neighborhood-level as opposed to the household level, once again controlling for contextual interactions that may drive common behavior within neighborhoods. We construct a number of neighborhood-level variables within a 500-meter buffer of each house. Figures 2 and 3 show the size of the 100-meter buffer relative to the 13 nearest neighbors, and illustrates how this definition of the neighborhood varies with the density of the area.

We construct the ratio of multifamily to total buildings, as well as the ratio of commercial/industrial buildings to total buildings. Both variables capture potential sorting of individuals into different types of neighborhoods and proxy for many unobservables such as available amenities and disamenties from shopping to traffic. We also include the percentage of owner-occupied houses in the neighborhood as neighborhoods with shorter tenure are more likely to have been recently developed and are also more likely to have weaker social connections among residents. Because houses in these neighborhoods are therefore more likely to foreclose and because there is no definitive measure from the literature we include the 25th percentile, 50th percentile, and 75th percentile tenure values to eliminate the influence of outliers. We also include the median age of the homes in the neighborhood.

Loans.—Gerardi, Shapiro, and Willen (2009) find that households with subprime loans are more likely to enter into foreclosure. To the extent that subprime loans went to low-income households, the prevalence of subprime loans in a community can be thought of as a correlated effect—that is, communities with more subprime loans are more likely to experience higher foreclosure rates because the types of households with subprime loans are correlated. Indeed, as discussed in Gerardi and

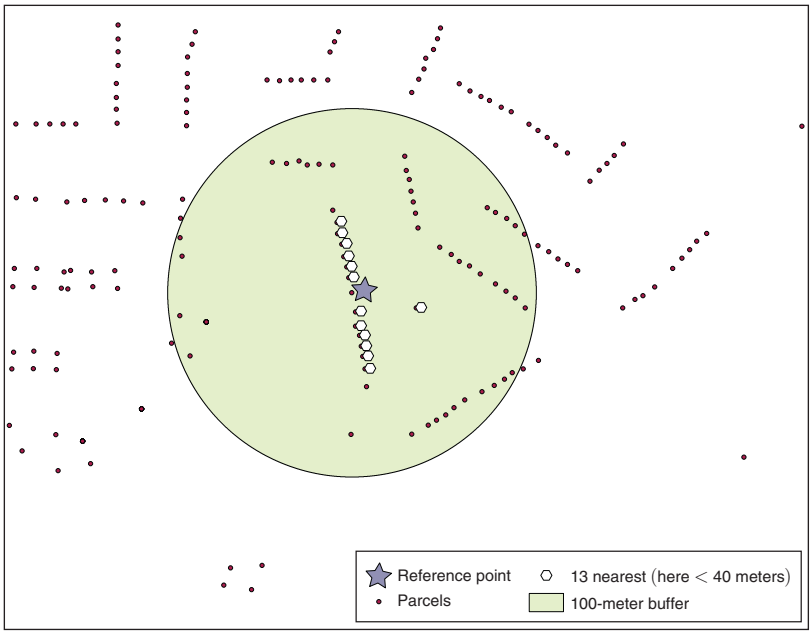

FIGURE 2. BUFFER ILLUSTRATION FOR DENSE AREA

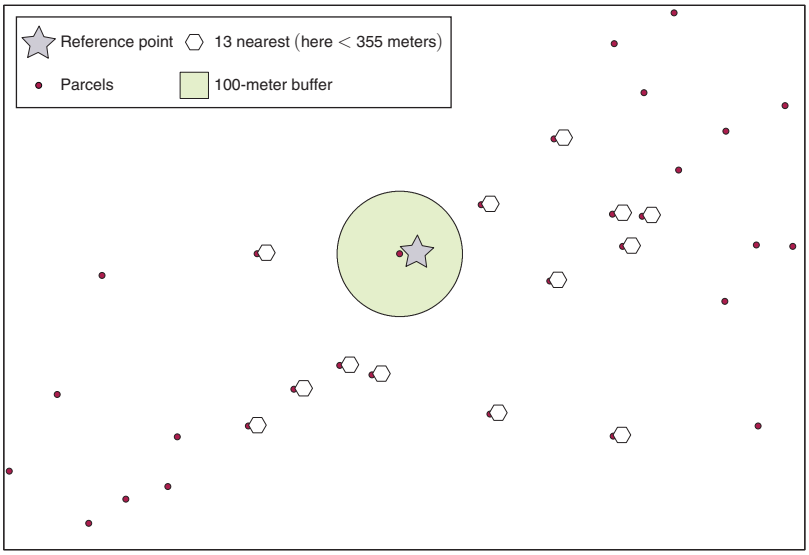

FIGURE 3. BUFFER ILLUSTRATION FOR RURAL AREA

Willen (2009), borrowers that use the subprime market tend to have poorer credit histories, higher initial loan-to-value ratios, and high debt-to-income ratios. We calculate a two-year moving average of subprime loans by census, where a loan is considered subprime when the rate spread is greater than three percentage points on the first lien and more than five percentage points on subordinate liens, as defined by the HMDA data.[10]

Because the interaction of loan amounts and sales values are important in identifying speculative areas, we include a number of additional variables characterizing loan activity at the census tract level that are updated every year of the analysis window. These variables include the ratio of loan amount to recent average sales values (refinance and new purchase separately) to identify rapidly appreciating areas and the ratio of loan amount to average assessed value to identify areas that have departed dramatically from the tax value as of 2005.[11] The percentage of loans that are subprime or were granted to minority applicants in each rolling two year window prior to the current analysis year are also included. More than 17 percent of loans in the two-year window are subprime loans.

House Prices and Unemployment.—It is clear that decreases in house prices increase the likelihood of foreclosure (Bajari, Chu, and Park 2010). Foote, Gerardi, and Willen (2008), using a town-level house price index to measure the equity position of households, present evidence that negative equity, brought about by house price depreciation, increases the likelihood of foreclosure. Gerardi, Shapiro, and Willen (2009) show that foreclosures tend to be driven by house price depreciation as opposed to insufficiently cautious underwriting. We include an annual repeat sales house price index at the census tract level where there is adequate sample to estimate the index, and at the census subdivision level where the sample is not adequate.[12] We also use the repeat sale price index to calculate the percentage off peak values of the house price index. House price index variables control for contextual interactions due to variation in house price expectations at the county census subdivision level. The peak year values range from 2005 to 2008 with 49 percent of the sample experiencing peak prices in 2006 and another 40 percent in 2007. Additionally, we include an average tract level sales price and average assessed amount for a two-year window by census tract and the ratio of average sales value to average assessed value. Both of these serve as proxies for comparable sales and proxy for information the homeowners' have access to when forming their own price expectations.

To help assess the potential influence of unemployment on foreclosures in our sample area, we include a measure of the average unemployment rate at the city level, where available, or county level over the previous 12 months. There is mixed evidence regarding the importance of changes in unemployment in explaining foreclosure activity. Foote, Gerardi, and Willen (2008) find that a higher unemployment

[10] Mayer and Pence (2009) indicate that the definition of subprime loans is not unique. They conclude, however, that HMDA may provide the most comprehensive coverage of the prevalence of subprime loans.

[11] The assessment cycle is three years in these counties, so we use the assessed value from 2005 as the base for all calculations to avoid biases created by recent sales during our study period.

[12] We use 150 repeat sales as the cutoff. There are 1,216 tracts in the state of Maryland and 700 tracts in our analysis; 328 of these have the tract-level price index.

rate leads to an increase in foreclosure. Bajari, Chu, and Park (2008) find that a higher unemployment rate has a negative impact on the likelihood of foreclosure. Gerardi, Shapiro, and Willen (2009) find that changes in cumulative unemployment rates have no impact on foreclosures. We include measures of mean unemployment and the standard deviation in unemployment as a control for the exogenous influence of shocks to employment that are common within communities. It is difficult to know a priori how the measure of unemployment will interact in this model as it is, at best, a coarse approximation and, at worst, a misleading indicator of true financial stress due to employment status as it will miss reduced hours and underemployment as well as the long-term unemployed.

V. Results

Table 2 presents results from the Cox proportional hazard model with county fixed effects for the *all distressed* classification. This model allows us to assess the contribution of the full complement of covariates typically related to mortgage default, even those measured at the census tract level including socioeconomic, demographic, and loan attributes. Our results are generally consistent with the prior literature examining the causes of foreclosure, and since much has been hypothesized or conjectured about the contributions these more aggregate measures make to foreclosures, we discuss them briefly below. All results are expressed as hazard ratios, implying that values greater than one indicate that the independent variable increases the hazard of default, whereas values less than one indicate that the independent variable reduces the hazard of default.

Endogenous Interactions.—Overall, we find strong evidence that endogenous interactions influence home loan default decisions. The estimated hazard ratios on the endogenous interaction variable are significant in all of the models, and among the most statistically significant of all the variables in the model. A one-unit increase in neighboring foreclosures increases the hazard of foreclosure by as much as 28 percent. Additionally, it is evident from Table 2 that the results from the "tighter" neighborhood of 13 nearest neighbors have a greater impact on hazard ratios than does the broader neighborhood of 25 nearest neighbors, where a one-unit increase in the number of neighboring foreclosures increases the hazard of foreclosure by 23 percent. This result is consistent with previous research on the spatial contagion effect of foreclosures, which has provided evidence that the strength of the price-depressing effect of neighboring foreclosures decreases with distance (Harding, Rosenblatt, and Yao 2009; Campbell, Giglio, and Pathak 2011). This result is also an important robustness check on the definition of the social group; the tighter the group the larger the effect.[13]

[13] We estimated a series of models using different definitions of nearest neighbor, ranging from 75 nearest neighbors through to 10,000 nearest neighbors. We find that the contagion effect of neighboring foreclosures falls as the size of the group increases. These results are available upon request.

TABLE 2—COX MODEL SUBCLASSIFICATION: ALL DISTRESSED

	Nearest 13 neighbors		Nearest 25 neighbors	
	Hazard ratio	Robust SE	Hazard ratio	Robust SE
Endogenous Interaction				
Number of neighboring foreclosures	1.276***	0.011	1.225***	0.007
Household characteristics				
Owner-occupied	0.503***	0.006	0.503***	0.006
Current owner's tenure, less than 5 years	4.248***	0.166	4.249***	0.166
Current owner's tenure, 5 to 15 years	2.352***	0.094	2.351***	0.094
Current owner's tenure, 15 to 30 years	1.211***	0.052	1.211***	0.052
Age of home, less than 5 years	1.913***	0.046	1.903***	0.046
Age of home, 5 to 15 years	1.294***	0.024	1.297***	0.024
Age of home, 15 to 30 years	1.239***	0.018	1.237***	0.018
Condo	0.699***	0.015	0.705***	0.015
Townhouse	0.865***	0.023	0.863***	0.023
Low-quality house construction	1.655***	0.024	1.650***	0.023
Good-quality house construction	0.836***	0.019	0.839***	0.019
Very good quality house construction	0.843***	0.042	0.847***	0.042
Travel time to Baltimore	0.999	0.001	0.999	0.001
Travel time to Annapolis	0.998**	0.001	0.998***	0.001
Travel time to Washington, DC	1.007***	0.001	1.007***	0.001
Neighborhood and community characteristics				
Median income	1.000***	0.000	1.000***	0.000
Percent minority	1.002***	0.000	1.002***	0.000
Median rent	1.000	0.000	1.000	0.000
Percent with college education	1.000	0.001	1.000	0.001
Percent below poverty	1.000	0.002	1.000	0.002
Population density	1.001***	0.000	1.001***	0.000
Percentage of owner-occupied housing in 500-meter buffer	1.014***	0.001	1.014***	0.001
25th percentile tenure of residents in 500-meter buffer	0.950***	0.007	0.951***	0.007
50th percentile tenure of residents in 500-meter buffer	0.985***	0.005	0.987***	0.005
75th percentile tenure of residents in 500-meter buffer	1.003	0.002	1.003	0.002
Median age of residential properties in 500-meter buffer	1.004***	0.000	1.004***	0.001
Ratio of multifamily to total buildings in 500-meter buffer	0.998***	0.000	0.998***	0.000
Ratio of commercial to total buildings in 500-meter buffer	1.011***	0.001	1.011***	0.001
Average turnover of property in block last 5 years	1.056***	0.002	1.054***	0.002

Household Characteristics.—As with the endogenous interaction variables, results for the household characteristics are stable across a number of alternative model specifications and are generally consistent with expectations. We find that owner-occupiers are far less likely to go into foreclosure than are rental property owners. An owner-occupied house reduces the hazard rate of foreclosure by almost 50 percent. This is likely due to the fact that an owner-occupier must bear relocation costs in the event of a foreclosure, whereas a rental property owner does not. Households that have longer tenure periods are less likely to default and go into foreclose. A household with a current tenure in a home of less than 5 years is more than 4 times as likely to go into foreclosure as compared to a household with a current tenure of 30 years or more. Households with tenures between 5 and 15 and between 15 and 30 years are also more likely to go into foreclosure relative to a household with current tenure of 30 or more years. These results are consistent with the fact that households with longer tenure are more likely to have stronger

TABLE 2—COX MODEL SUBCLASSIFICATION: ALL DISTRESSED (*Continued*)

	Nearest 13 neighbors		Nearest 25 neighbors	
	Hazard ratio	Robust SE	Hazard ratio	Robust SE
Loan characteristics				
Ratio of conventional loan amount to average sales value by tract	0.991***	0.002	0.991***	0.002
Ratio of refinance loan amount to average sales value by tract	1.005***	0.002	1.005***	0.002
Ratio of conventional loan amount to average assessed amount by tract	1.003***	0.001	1.003***	0.001
Ratio of refinance loan amount to average assessed amount by tract	0.996***	0.001	0.996***	0.001
Applicant income for refinance applications	0.996***	0.000	0.996***	0.000
Applicant income for conventional loan applications	0.999***	0.000	0.999***	0.000
Loan for refinance applications	1.000*	0.000	1.000*	0.000
Loan for conventional applications	1.001***	0.000	1.001***	0.000
Minority share of loans	1.003***	0.000	1.002***	0.000
Subprime share of loans	1.039***	0.001	1.040***	0.001
House price and unemployment				
Repeat sales price index	1.001***	0.000	1.001***	0.000
Percent of most recent price index off the peak value	1.013***	0.001	1.012***	0.001
Ratio of average sales amount to average assessed amount by tract	1.027	0.032	1.030	0.032
Average sales value by tract	0.999***	0.000	0.999***	0.000
Assessed value	1.000***	0.000	1.000***	0.000
Average of 12-month unemployment rate	0.938***	0.012	0.941***	0.012
Standard deviation of previous 12-month unemployment rate	1.084	0.100	1.091	0.101
log likelihood	−568,673		−568,485	
Observations	1,071,786			
Failure events	42,375			

Sources: Home Mortgage Disclosure Act for loans, Bureau of Labor Statistics for unemployment data, and Maryland Property View (updated annually since 2006 and last updated in February 2011) for all other data.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

ties to their current communities and are therefore less willing to choose to default. Perhaps more important than ties to the community, households with longer tenures likely have lower loan-to-value ratios, both because they have had more time to pay down principle and because they were less likely to purchase during the house price boom.

We find that households in houses less than 5, between 5 and 15, and between 15 and 30 years old are far more likely to go into foreclosure as compared to homes built more than 30 years ago. For example, if a household is in a home less than five years old the hazard of default increases by 91 percent, compared to a household in a home thirty or more years old. Whereas previous research indicates that condo ownership is positively correlated with the likelihood of foreclosure (Gerardi, Shapiro, and Willen 2009), we find that multifamily dwellings are less likely to go into foreclose than single family properties. As mentioned previously, our study area is suburban so we have fewer condos and many nontraditional condominium owners such as retirees.

We find that houses of lower quality construction are more likely to foreclose as compared to houses of average quality construction. In fact, the effect of quality is quite large: the owner of a low-quality house is approximately 66 percent more likely to foreclose than is the owner of an average-quality house. We expect that quality of housing controls for household wealth, and if this is the case, then low-income households are more likely to foreclose. This is consistent with the notion that low-income households are less able to withstand income shocks and house price depreciation, and are therefore more likely to default and go into foreclosure.

Neighborhood and Community Characteristics.—Neighborhood and community characteristics are included in the hazard models as controls for the correlated effects that might otherwise cause neighbors to have a similar propensity to default and foreclose. We find that neighborhood and community characteristics are statistically significant in the majority of cases, but overall the impacts are small. Greater population density tends to increase the likelihood of foreclosure, and households in census tracts with higher percentage minority populations are more likely to go into foreclosure. Interestingly, we see that areas where the percentage of loans to minorities is greater also tend to default at higher rates, though again the effect is very small.

Hazard ratio estimates for the neighborhood characteristics are stable across all model specifications. We find that the length of time a household's neighbors have lived in the neighborhood can have a significant impact on the likelihood of foreclosure, implying that new communities were at risk. For example, an increase in tenure among households' newest neighbors reduces the likelihood of foreclosure by as much as 5 percent. An increase in the median age of neighboring structures and an increase in the amount of commercial development in the neighborhood increases the hazard rate of foreclosure slightly. Finally, households in census block groups with a higher average property turnover rate tend to be more likely to default, with a one-unit increase in the average turnover rate increasing the hazard rate of default and foreclosure by 5 percent to 6 percent in both of the hazard model specifications. This result is consistent with the notion that households have fewer ties in less stable communities as well as the communities where speculative purchases and property flipping may have been most prevalent.

Loan Characteristics.—Overall, loan characteristics influence the likelihood of foreclosure. Our results suggest that the primary loan characteristic influencing foreclosure is the subprime share of loans. Households in census tracts with a greater percentage of subprime loans as a share of all new residential loans are more likely to default. One can think of the coefficient on the subprime variable as an elasticity; for each 1 percent increase in subprime loans the hazard of default increases by 4 percent. These results are consistent with previous research indicating that subprime loans go to riskier borrowers and are more sensitive to depreciation in house values (Geradri, Shapiro, and Willen 2009). In areas where subprime loans are upwards of 30 percent of the new loan portfolio, which are not uncommon in our study area, this puts subprime loans at a magnitude of impact equal to or greater than the social interaction effects we discussed previously. Additionally from the loan variables, we see that higher incomes correlate to lower hazard rates of default.

House Prices and Unemployment.—In general, the results pertaining to observed prices and the dynamics of price changes conform to expectations. Households in areas that have experienced a larger house price collapse have a higher hazard rate of foreclosure. This suggests that the greater the fall in house prices (from their peak), the greater the likelihood of foreclosure. Evaluating these at the average national decline of 29 percent implies an approximate 29 percent increase in the hazard rate of default.

Finally, the unemployment rate (over the previous 12 months) has an odd relationship to the hazard of foreclosure, implying that higher unemployment reduces the hazard rate. This is somewhat surprising considering the fact that job loss is typically a factor that increases the likelihood of foreclosure. This result could simply reflect the fact that the job outlook in this region is better than the next best alternative in another region. Our results may also reflect the fact that job loss was not a primary cause of Maryland foreclosures; underemployment or overextended borrowers may have been more significant causal factors.

A. *Classification of Distressed Properties*

The results presented in Table 2 were based on the *all distressed* classification. It is possible that this measure of distressed properties is too broad and properties that do not eventually complete the foreclosure process do not experience as large of an endogenous interaction effect as those that do complete the foreclosure process. An alternative measure of distressed properties includes only properties that completed the foreclosure process by January 2011, the *completed foreclosures* classification. This classification may miss properties still in the foreclosures process in January 2011 or short sale properties. To the extent that these missing properties were subject to an endogenous interaction effect, the *completed foreclosures* classification may not capture the full strength of the endogenous interactions.[14]

Table 3 presents Cox proportional models based on the *completed foreclosures* classification. The estimated hazard rates on the endogenous interaction variables are slightly higher when the distressed properties are restricted to those that complete the foreclosure process. An additional neighboring foreclosure among the nearest 25 neighbors increases the hazard rate of foreclosure by 25 percent. As is the case in the *all distressed* model, the endogenous interaction effect is stronger among the nearest 13 neighbors. An additional neighbour among the nearest 13 increases the hazard rate of foreclosure by 31 percent.

B. *Unobserved Heterogeneity*

In this section we present results from our preferred specification, which addresses a potential issue with group sorting behavior related to correlated effects. It is possible that people more likely to default are also more likely to live next to one another. It is difficult to define exactly what form this variable would take that would not be correlated with our disaggregate measures of properties, price

[14] As discussed in the data description, the endogenous interaction is measured based only on neighboring parcels that have received a default notice and ultimately complete the foreclosure process.

TABLE 3—COX MODEL SUBCLASSIFICATION: COMPLETED FORECLOSURE

	Nearest 13 neighbors		Nearest 25 neighbors	
	Hazard ratio	Robust SE	Hazard ratio	Robust SE
Endogenous interaction				
Number of neighboring foreclosures	1.310***	0.016	1.254***	0.010
Household characteristics				
Owner-occupied	0.297***	0.005	0.299***	0.005
Current owner's tenure, less than 5 years	4.571***	0.251	4.577***	0.251
Current owner's tenure, 5 to 15 years	2.072***	0.117	2.074***	0.117
Current owner's tenure, 15 to 30 years	0.996	0.061	0.997	0.061
Age of home, less than 5 years	1.815***	0.056	1.804***	0.061
Age of home, 5 to 15 years	1.206***	0.033	1.209***	0.033
Age of home, 15 to 30 years	1.242***	0.025	1.239***	0.025
Condo	0.692***	0.021	0.699***	0.021
Townhouse	0.770***	0.028	0.769***	0.028
Low-quality house construction	1.866***	0.037	1.861***	0.036
Good-quality house construction	0.886***	0.028	0.890***	0.029
Very good quality house construction	0.923	0.065	0.927	0.066
Travel time to Baltimore	0.998	0.001	0.999	0.001
Travel time to Annapolis	1.003**	0.001	1.003*	0.001
Travel time to Washington, DC	1.003**	0.001	1.003**	0.002
Neighborhood and community characteristics				
Median income	1.000***	0.000	1.000***	0.000
Percent minority	1.002***	0.001	1.001***	0.001
Median rent	1.000**	0.000	1.000**	0.000
Percent with college education	1.001	0.001	1.001	0.001
Percent below poverty	1.000	0.003	0.999	0.003
Population density	1.001***	0.000	1.001***	0.000
Percentage of owner-occupied housing in 500-meter buffer	1.017***	0.001	1.017***	0.001
25th percentile tenure of residents in 500-meter buffer	0.964***	0.012	0.966***	0.012
50th percentile tenure of residents in 500-meter buffer	0.982**	0.007	0.984**	0.007
75th percentile tenure of residents in 500-meter buffer	1.004	0.003	1.004	0.003
Median age of residential properties in 500-meter buffer	1.004***	0.001	1.004***	0.001
Ratio of multifamily to total buildings in 500-meter buffer	0.999***	0.000	0.999***	0.000
Ratio of commercial to total buildings in 500-meter buffer	1.012***	0.001	1.011***	0.001
Average turnover of property in block last 5 years	1.066***	0.003	1.064***	0.003

histories, and neighborhoods. In an attempt to address this potential issue we estimate and present as our main result a piece-wise exponential model that includes fixed effects at the lowest level of aggregation computationally possible (the census block group)[15] and that allows the baseline hazard to vary by year. [16] The inclusion of census block group fixed effects controls for any confounding time-invariant unobserved heterogeneity that specifically defines or causes homeowners with a proclivity to default to also live in the same neighborhood. Table 4 presents results for the endogenous interactions coefficients across a full range of fixed and random

[15] These "nuisance parameters" will not increase with sample size and thus are not likely to present classic incidental parameters inconsistencies.

[16] A likelihood ratio test rejects the exponential baseline versus a monotonic Weibull baseline, suggesting the baseline hazard should be allowed to change over time. Using fixed/random effects and allowing the baseline hazard to vary each year controls for the potential impacts of foreclosure moratoria and loan modification programs on foreclosures. Our baseline results are robust to the inclusion of tract-year interactions. The inclusion of more refined time-geographic fixed effect interactions is too computationally intensive for the hazard model to run.

TABLE 3—COX MODEL SUBCLASSIFICATION: COMPLETED FORECLOSURE (*Continued*)

	Nearest 13 neighbors		Nearest 25 neighbors	
	Hazard ratio	Robust SE	Hazard ratio	Robust SE
Loan characteristics				
Ratio of conventional loan amount to average sales value by tract	0.992***	0.002	0.992***	0.003
Ratio of refinance loan amount to average sales value by tract	1.001	0.002	1.002	0.002
Ratio of conventional loan amount to average assessed amount by tract	1.002**	0.001	1.003**	0.001
Ratio of refinance loan amount to average assessed amount by tract	0.998**	0.001	0.997**	0.001
Applicant income for refinance applications	0.996***	0.001	0.996***	0.001
Applicant income for conventional loan applications	0.999***	0.000	0.999***	0.000
Loan for refinance applications	1.001**	0.000	1.001**	0.000
Loan for conventional applications	1.001**	0.000	1.001**	0.000
Minority share of loans	1.000	0.001	1.000	0.001
Subprime share of loans	1.046***	0.002	1.047***	0.002
House price and unemployment				
Repeat sales price index	1.002***	0.000	1.001***	0.000
Percent of most recent price index off the peak value	1.013***	0.001	1.012***	0.001
Ratio of average sales amount to average assessed amount by tract	1.017	0.045	1.010	0.046
Average sales value by tract	0.999**	0.000	0.999**	0.000
Assessed value	0.999***	0.000	0.999***	0.000
Average of 12 month unemployment rate	0.905***	0.017	0.909***	0.017
Standard dev. of previous 12 month unemployment rate	0.785*	0.104	0.792*	0.105
log likelihood	−284,540		−284,416	
Observations	1,071,786			
Failures	21,532			

Sources: Home Mortgage Disclosure Act for loans, Bureau of Labor Statistics for unemployment data, and Maryland Property View (updated annually since 2006 and last updated in February 2011) for all other data.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

effects models estimated at different levels of geographic aggregation.[17] These results suggest that accounting for correlated attributes at the disaggregated scale of census block group does control for correlated effects. In the model with census block group fixed effects, we find that a one-unit increase in the number of neighboring foreclosures increases the hazard rate of foreclosure by 18 percent. We also show that the estimated hazard ratios tend to increase as the level of geographic aggregation increases, such that a one-unit increase in the number of neighboring foreclosures increases the hazard rate of foreclosure by between 15 percent and 28 percent, moving from block level to county level effects.

Our results suggest that the magnitude of the contagion effect is sensitive to the level of aggregation of geographic controls for correlated unobservables. The model with census block group fixed effects provides a conservative estimate of the endogenous interaction. In fact, even when controlling for correlated unobservables

[17] We did not estimate a fixed effects model for the block level model due to the large amount of computational time required (the full fixed effects model at the block level includes more than 14,000 fixed effects).

Table 4—Models with Grouped Effects Subclassification: All Distressed

	County		Tract		Block group		Block
	Fixed effect	Random effect	Fixed effect	Random effect	Fixed effect	Random effect	Random effect
25 Nearest neighbors							
Number of neighboring defaults	1.230***	1.230***	1.183***	1.197***	1.146***	1.174***	1.132***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
13 Nearest neighbors							
Number of neighboring defaults	1.284***	1.287***	1.223***	1.240***	1.180***	1.212***	1.154***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)
Number of homes	1,071,786						
Number of groups	5		676		1,894		13,958
Observations	214,357		1,585		566		77

Note: Standard errors in brackets.

Sources: Home Mortgage Disclosure Act for loans, Bureau of Labor Statistics for unemployment data, and Maryland Property View (updated annually since 2006 and last updated in February 2011) for all other data.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

at the census block (approximately 79 houses per block) we find significant endogenous interaction effects in line with the results of the census block group model. Overall, these results suggest that group sorting behavior at the very disaggregate neighborhood level is not driving the endogenous interaction results.

VI. Conclusions

Using a unique and highly disaggregate dataset, we reveal the existence of an important but heretofore unexplored behavioral aspect of the recent foreclosure crisis. We find strong evidence suggesting that endogenous interactions among neighbors influence the likelihood of default and foreclosure, controlling for a multitude of factors that typically impact the likelihood of foreclosure. Specifically, our main results suggest a one-unit increase in the number of neighboring foreclosures increases the likelihood of default and foreclosure by at least 18 percent. These hazard ratio estimates translate into an increase in the probability of default during the sample period from 4.4 percent with zero neighboring foreclosures to 6.5 percent with 4 (of 13) neighbors in foreclosure. This is a conservative estimate of the feedback effect and seems to exceed the effects one would expect from a temporary reduction in local house prices.

Our results suggest that endogenous interactions, other than the constraint interactions associated with price decreases, play a significant role in the observed endogenous interaction. In particular, our results are consistent with the notion that as households observe others in foreclosure they are more likely to default on their home loans. This is consistent with the presence of significant expectation and preference interactions, as would arise when neighboring foreclosures alter households' expectations of the future trajectory of their neighborhood, or alter their perceptions

of the stigma or moral constraints on foreclosure. The negative feedback that we have identified as arising from endogenous interactions among neighbors lends support to the widespread concern that foreclosures can have multiplier effects within neighborhoods, potentially leading to a cycle of foreclosures.

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