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School segregation and the foreclosure crisis☆

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ABSTRACT

One overlooked consequence of America's foreclosure crisis is the impact it had on school segregation. Using data on Florida schools, we find that the crisis reduced the racial segregation of elementary schools by opening up affordable housing opportunities to black families in predominantly white neighborhoods. Our analysis has the added importance of providing a natural experiment testing whether more affordable housing in predominantly white school attendance zones will decrease segregation.

1. Introduction

The housing crisis in the United States during the Great Recession spurred an enormous amount of research on the causes and consequences of residential foreclosures. The breadth of topics in this literature is impressive, but one important social issue has gone completely unstudied: namely, the impact of the foreclosure crisis on school segregation.[1] The tendency of black students to be segregated into mostly black schools continues to be one of America's most vexing social problems, especially in light of recent compelling evidence that segregation has adverse effects on student achievement and lifetime success.[2]

The premise of our investigation is that because public school assignments in the U.S. are largely determined by where a student lives, the problem of racial segregation in the public school system is driven primarily by the spatial concentration of different types of housing units within a school district. For instance, given lower minority homeownership rates, concentrating a district's rental housing stock in a small number of school attendance zones can give rise to high levels of school segregation. To get a sense of just how strong the relationship is between the spatial concentration of housing and school segregation, in Fig. 1 we have plotted the black-white dissimilarity index for the schools that we analyze in Florida against the Theil Information Index defined over the following types of housing units broken down by both affordability status and tenure status: single-family units, condominium units, and multi-family units.[3] Both of these indices range from 0 to 1. In the case of the dissimilarity index, higher index values reflect an increasing level of segregation between white and black public elementary school students. Higher levels of the Theil index reflect lower levels of heterogeneity in the housing stock in a district's elementary school boundaries.[4]

A simple regression of the dissimilarity index on the Theil index reveals that the spatial concentration of the housing stock explains nearly half of the variation of black-white student segregation in our data. If we interpret this figure as a summary of the equilibrium relationship between school segregation and the intra-district spatial distribution of housing, this simple plot suggests that any shocks to the spatial distribution of the housing stock within a school district have the potential to exert significant influence on school segregation patterns. The primary contribution of this paper is to provide the first evidence on how one particular supply shock – the recent foreclosure crisis – affected segregation.

☆ The views expressed in this paper are those of the authors and do not necessarily reflect those of the Office of the Comptroller of the Currency or the U.S. Department of the Treasury.

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[1] As a sampling of this literature: for the effects of foreclosures on the values of nearby properties, see Ihlanfeldt and Mayock (2016b); on crime, see Ellen et al. (2013); on local government budgets, see Ihlanfeldt and Mayock (2015); on children's schooling outcomes, see Figlio et al. (2011); and on credit scores, see Brevoort and Cooper (2013).

[2] For a review of the evidence see Epple and Romano (2011) and Harris (2006). For documentation of recent trends in segregation, see Orfield et al. (2016) and GAO (2016).

[3] The construction of these indices is discussed in Appendix A, and our sample is described in Section 4.

[4] For example, the Theil index would be very high in a case where a school district's elementary school catchment boundaries contained either owner-occupied single-family units or renter-occupied multi-family units, but no mix of the two types of housing.

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Because of the link between residential location and public school assignment, foreclosures can impact school segregation if and only if foreclosure activity induces a re-sorting of students across school attendance boundaries. We examine this re-sorting of black and white households in response to changes in the prevalence of Real Estate Owned (REO) properties, which are homes that are owned by financial institutions as a result of foreclosure proceedings, and properties that were previously in REO status ("recent REOs") that were subsequently sold to owner-occupiers or investors.[5,6]

There are three channels through which the foreclosure crisis may have induced such household mobility. First, foreclosure generally results in the relocation of the defaulting homeowner, and existing work has shown that most homeowners move to different neighborhoods after defaulting on their mortgage (Molloy and Shan, 2013).[7] Second, previous research has demonstrated that properties currently in REO status and recent REOs that become rental units both produce negative spillover effects which cause housing prices in the neighborhood to fall (Ihlanfeldt and Mayock, 2016a).[8] Foreclosure-related externalities can thus alter the relative price of housing services in black and white neighborhoods, inducing a re-sorting of black and white families with school-age children across different school catchment boundaries; these relative price changes have the potential to either increase or reduce school segregation. When REOs are sold to investors, there is a third mechanism that may induce sorting across neighborhoods. Recent REO single-family rental properties were frequently located in neighborhoods where the supply of rental housing had previously been very low (Ihlanfeldt and Mayock, 2016a). The foreclosure crisis thus created the opportunity for renter households to relocate to neighborhoods that were previously almost exclusively populated by owner-occupants.[9,10]

In this paper we investigate the impact of the foreclosure crisis on the racial segregation of elementary schools.[11] We conduct this investigation using a panel of Florida school districts from 1998 through 2013. With our panel, we seek to explain changes in five popular measures of segregation as a function of areal-based changes in the number of foreclosure completions and the number of homes that recently transitioned out of bank-owned status.

Our key finding is that the foreclosure crisis produced statistically significant declines in three of the five segregation indices that we analyze. The most popular index, the dissimilarity index, fell on average by about five percent between 2005 and 2013 in our sample, but for some larger districts the change is more than twice as large. All in all, our findings suggest that the foreclosure crisis provided black households with housing opportunities in white neighborhoods that they otherwise would have found unaffordable.

A common argument in the school segregation literature is that black students are segregated from white schools due to an absence of affordable housing in primarily white neighborhoods (Schwartz, 2010; Rothwell, 2012; Lens and Monkkonen, 2016). Policy prescriptions to address this dearth of housing opportunities for black households in white neighborhoods have included reducing exclusionary zoning, adopting inclusionary zoning, and counseling voucher recipients on housing opportunities that exist in white neighborhoods. However, it is not a foregone conclusion that such policies would work. First, black families may not be interested in moving to predominantly white neighborhoods. Concerns other than improving their child's school environment – such as access to public transit, job opportunities, or social services – may be the primary determinant of the location decisions of many black households. Second, the parents of black children may be concerned that their child would be uncomfortable in a majority white school. Third, even if black households are willing to live within the attendance boundaries of predominantly white schools, they may be excluded from these neighborhoods because of discrimination on the part of housing suppliers.[12] Unfortunately, we were unable to find a single study providing evidence on the efficacy of using affordable housing policy to desegregate schools. There is a simple reason for the lack of research on this topic. Before the Great Recession, high-income neighborhoods throughout the U.S. successfully used anti-density zoning (and Not-in-My-Backyard resistance) to effectively eliminate the supply of affordable and rental housing (Rothwell, 2012), leaving researchers with little variation with which to study the impact of expanded housing opportunity on segregation. The foreclosure crisis, however, resulted in a surge in the affordable housing stock in high-income neighborhoods; we exploit this variation to study how expanding housing opportunity for low- and moderate-income households affects school segregation.

In the next section (Section 2) we develop a simple model for thinking about the avenues whereby foreclosures and recent REO

[5] Previous research has found that most investor-acquired properties are offered for rent, as opposed to being held for speculation purposes (Ellen et al., 2012; Immergluck, 2012).

[6] After a property is repossessed by a financial institution following foreclosure, the property is generally vacant until it is resold to a new homeowner. In some rare cases, REOs are not vacant. Such cases include when an REO is occupied illegally by squatters or when the financial institution that owns the REO rents it out prior to disposition.

[7] Molloy and Shan (2013) find that nearly half of the individuals that had started the foreclosure process had moved within three years, whereas only a quarter of households not facing foreclosure relocated. Most importantly for our analysis, less than 10% of the post-foreclosure movers between 2006 and 2008 relocated within the same Census tract. Although school catchment boundaries are not coterminous with those of tracts, this finding suggests that most young children in households facing foreclosure eventually changed elementary schools. It is worth noting that in our analysis below, we focus on the impact of foreclosure completions whereas Molloy and Shan (2013) study foreclosure starts. As foreclosure proceedings are frequently initiated and not completed, we have reason to believe that our foreclosure completion variables are associated with moves at higher rates than those reported in Molloy and Shan (2013). An additional pertinent finding from their study is that while a post-foreclosure move generally triggers a change in neighborhood, the neighborhood to which the household relocates is generally quite similar in terms of its demographic characteristics to the household's previous neighborhood.

[8] There are three prominent hypotheses regarding the mechanisms generating these negative spillover effects. First, because REO properties are typically listed for sale, they expand the for-sale inventory, depressing prices. Anenberg and Kung (2014) find strong support for this inventory mechanism. Second, bank-owned properties are frequently in poor physical condition, and home buyers may command a discount for properties located nearby poorly-maintained homes. Gerardi et al. (2015) provide support for this view. Lastly, several authors have posited that REOs generate criminal activity, which in turn reduces the value of nearby homes. For a review of this literature, see Ellen and Lacoe (2015).

[9] Molloy and Shan (2013) found that after foreclosure most households in their sample continued to live in single-family housing, did not have a mortgage reported with the credit bureau, and did not appear to have moved in with family members. Although tenure status is unobserved in their data, such households are likely renting single-family units. The transition of foreclosed homes to rental properties – particularly single-family units – may thus allow for households that lost their homes to foreclosure to remain in the same neighborhood.

[10] While we are unaware of any data that report annual neighborhood-level homeownership rates, there is reason to believe that an increase in a neighborhood's foreclosure activity reduces the homeownership rate. Most foreclosures occurred on housing units that were owner-occupied, and a large share of foreclosures were ultimately sold to investors that rented the properties to tenants following the REO process. All else equal, the transition of foreclosed homes from owner-occupied to renter-occupied units would reduce a neighborhood's homeownership rate.

[11] The results we report in this paper are restricted to blacks and non-Hispanic whites. We also conducted our analysis for whites and Hispanics. They show that in comparison to segregation between blacks and whites, the foreclosure crisis had a more modest effect on white-Hispanic school segregation.

[12] The U.S. Department of Housing and Urban Development's fair housing audits continue to show that black and Hispanic applicants are discriminated against within local housing markets (Turner et al., 2013). While this evidence provides a gauge of the overall level of discrimination within metropolitan areas, there is reason to believe that discrimination within high-income neighborhoods may be higher than average. William Fischel's "Homevoter Hypothesis" (Fischel, 1985, 2001) maintains that homeowners will go to great lengths to protect their property values. He shows that homeowners are aware of the positive effect that a good school can have on their home's value. If homeowners believe that minority students may tarnish the school's reputation, they may be particularly virulent in keeping minority families from moving into their neighborhood.

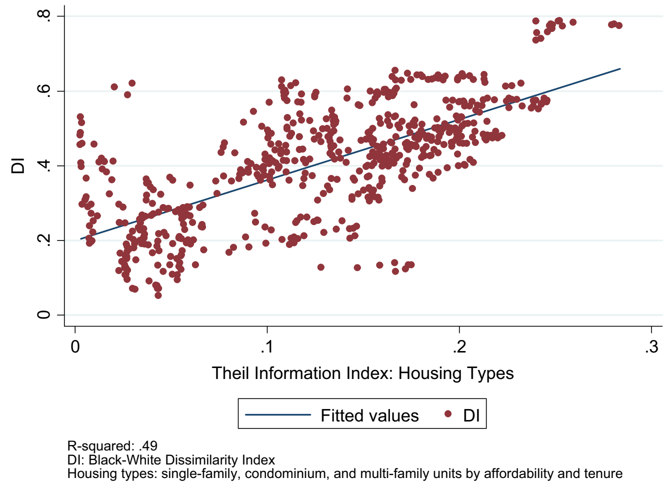

Fig. 1. Racial segregation and the spatial distribution of different housing types.

properties may affect school segregation. Section 3 reviews prior studies pertinent to our analysis. Our data and empirical methodology are described in Sections 4 and 5, respectively. Our results are presented in Section 6 and Section 7 contains our conclusions.

2. Conceptual framework

2.1. Model

To motivate our empirical work, we develop a simple two-period model of the impact of foreclosures - which are modeled as shocks to the supply of low-quality housing - on residential sorting. The basic structure of the model is a simple extension of Moretti (2011) and Moretti (2013), but whereas he is interested in studying the allocation of different types of workers across labor markets, our model is designed to study the spatial allocation of households across neighborhoods.

Let there be two types of housing units: high-quality (H) and low-quality (L). The economy is closed, and households can choose their residential location from two neighborhoods: Neighborhood A and Neighborhood B. Each household consumes one unit of housing. While households are free to choose between neighborhoods, we assume that low-income households are restricted to purchasing housing services in the low-quality market and high-income households only purchase housing services in the high-quality market. Let t index time periods, N_t^{Lq} denote the low-income households living in Neighborhood q, and N_t^{Hq} denote the high-income households living in Neighborhood q. The high-income and low-income households earn incomes of W_H and W_L, respectively. The cost of consuming low-quality housing in Neighborhood q is P_t^{Lq}, and the cost of high-quality units is denoted P_t^{Hq}. Consumers derive utility from residing in Neighborhood q through a common amenity package (γ_t^q) that is enjoyed by all consumers and a consumer-specific preference shock (ε_{Lit}^q, ε_{Hit}^q) that characterizes the match between a particular household and a neighborhood.

The indirect utility for a low-income household living in Neighborhood q is

$$U_{it}^{Lq} = W_L - P_t^{Lq} + \gamma_t^q + \varepsilon_{Lit}^q$$

and the indirect utility for a high-income household living in Neighborhood q is

$$U_{it}^{Hq} = W_H - P_t^{Hq} + \gamma_t^q + \varepsilon_{Hit}^q$$

We assume that the idiosyncratic components of households' preferences are distributed as

$$v_{Li} \equiv \varepsilon_{Lit}^A - \varepsilon_{Lit}^B \sim U[-s_L, s_L]$$
$$v_{Hi} \equiv \varepsilon_{Hit}^A - \varepsilon_{Hit}^B \sim U[-s_H, s_H]$$

The parameters s_L and s_H determine the extent to which residential location choice is driven by households' idiosyncratic preferences for particular neighborhoods. When s_L or s_H is large, the variation in individual-specific tastes for a given area is large, and mobility is limited. In the degenerate case when these parameters are zero, consumers are perfectly mobile.[13]

The stock of housing is taken to be exogenous in the initial period. Let H_{q0}^H and H_{q0}^L denote the total stock of high- and low-quality housing units in Neighborhood q in $t = 0$, respectively. At the end of period $t = 0$, F_A^H of the high-quality units in Neighborhood A are foreclosed upon.[14] Because of deferred maintenance associated with the foreclosure and REO process, these foreclosed homes become low-quality units in period $t = 1$.[15]

If γ_0^A and γ_0^B denote the amenity levels in Neighborhood A and B, respectively, in $t = 1$, we assume that amenity levels evolve as

$$\gamma_1^A = \gamma_0^A + \beta_A F_A^H$$
$$\gamma_1^B = \gamma_0^B$$

If foreclosures reduce the attractiveness of a neighborhood as has been hypothesized in the literature, then $\beta_A < 0$. If foreclosures have no impact on neighborhood amenities, then $\beta_A = 0$.

Let C_{q1}^H and C_{q1}^L denote the level of new construction in Neighborhood q of high- and low-quality housing, respectively. Beyond the foreclosure-induced quality changes, we assume that homes are infinitely-lived and do not depreciate. Under these assumptions, the housing stock for the various neighborhood-quality combinations in $t = 1$ can be written as

$$H_{A1}^H = H_{A0}^H - F_A^H + C_{A1}^H$$
$$H_{B1}^H = H_{B0}^H + C_{B1}^H$$
$$H_{A1}^L = H_{A0}^L + F_A^H + C_{A1}^L$$
$$H_{B1}^L = H_{B0}^L + C_{B1}^L$$

For both housing-quality types, we assume that new construction is dictated by the following upward-sloping new-construction functions.

$$P_1^{Hq} = \alpha^H + k^H C_{q1}^H$$
$$P_1^{Lq} = \alpha^L + k^L C_{q1}^L$$

where k^H and k^L are assumed to be positive. When geography or local regulations make increasing the supply of low-quality housing difficult, k^L is large and the supply for low-quality units is relatively inelastic. In contrast, when k^L approaches zero, supply approaches perfect elasticity. By similar logic, when there are few limitations to constructing high-quality units, k^H is small, and when the converse is true, k^H is large.

A low-income household chooses to live in Neighborhood A in $t = 1$ if $U_{i1}^{LA} > U_{i1}^{LB}$; otherwise, the household chooses to live in Neighborhood B. Likewise, a high-income household choose to live in Neighborhood A

[13] If we think of the households consuming low-quality housing as renters, then because renters are more mobile than homeowners, we would expect s_L to be smaller than s_H.

[14] If we think of the high-quality homes as being owner-occupied units, then the assumption that foreclosures only occur on high-quality homes is consistent with the fact that the vast majority of foreclosures during the most recent housing crisis occurred on owner-occupied residences.

[15] Note that our theoretical model does not differentiate between REOand recent REOproperties: homes in our model move directly from foreclosed status at the end of $t = 0$ into the low-quality housing stock in $t = 1$. That is, there is no period in our theoretical model in which a property is bank-owned and not available for occupancy. In the context of our empirical work, in our theoretical model we implicitly assume that REOs and recent REOs have the same impact on segregation. This assumption is supported by our empirical results.

if $U_{i1}^{HA} > U_{i1}^{HB}$ and chooses to live in Neighborhood B if $U_{i1}^{HA} \leq U_{i1}^{HB}$.

Let $\bar{v}^L$ denote the value of v_{Li} for the low-income household that is indifferent between Neighborhood A and Neighborhood B, and define $\bar{v}^H$ similarly for high-income households. That is, define $\bar{v}^L$ and $\bar{v}^H$ as

$$\bar{v}^H = P_1^{HA} - P_1^{HB} + \gamma_1^B - \gamma_1^A$$
$$\bar{v}^L = P_1^{LA} - P_1^{LB} + \gamma_1^B - \gamma_1^A$$

The total number of high- and low-income households in the economy are denoted N_1^H and N_1^L, respectively.[16] Because we only have two neighborhoods in the economy, to streamline the exposition, in what follows we will focus on the high- and low-income Neighborhood A populations.

$$N_1^{HA} = N_1^H\left(\frac{s_H - \bar{v}^H}{2s_H}\right)$$
$$N_1^{LA} = N_1^L\left(\frac{s_L - \bar{v}^L}{2s_L}\right)$$

Equilibrium in this model is defined as a set of prices, housing stocks, new construction levels, and neighborhood population levels such that the total housing stock for each income class in a neighborhood is equal to the total number of households of that income class that choose to live in that neighborhood.

We can differentiate the equilibrium values with respect to the foreclosure shock in Neighborhood A to study the model's predictions regarding the relationship between foreclosures and the distribution of the different household types across neighborhoods. In what follows, let x^* denote a variable x's equilibrium value in the system. The impact of a one-unit increase in foreclosure activity on the equilibrium level of the low-income population living in Neighborhood A (N^{*LA}) can be expressed as

$$\frac{\partial N^{*LA}}{\partial F_A^H} = \frac{(\beta_A + k^L)N^L s_L}{2(1 + k^L N^L s_L)}$$

The expression above will be positive if $(\beta_A + k^L)$ is positive. β_A captures the magnitude of the spillover effect on amenities. If there is no impact of foreclosures on neighborhood quality, then $\beta_A = 0$, $\frac{\partial N^{*LA}}{\partial F_A^H} > 0$, and an increase in foreclosures in Neighborhood A increases the fraction of the low-income residents that are living in Neighborhood A. Said differently, when $\beta_A = 0$, the foreclosure shock has no impact on the demand for low-income housing in Neighborhood A. Foreclosures do, however, increase the supply of low-quality housing, driving down prices and increasing the equilibrium number of low-income residents in the community.

Previous work (Ihlanfeldt and Mayock, 2016b) suggests that β_A is likely to be small or zero in areas with a high concentration of low-income residents. Thus, our framework predicts that when the foreclosure shock occurs in low-income areas, socioeconomic segregation should increase as the foreclosure shock results in a higher concentration of low-income residents in the neighborhood that received the shock.

When foreclosures reduce the amenity level in Neighborhood A, $\beta_A < 0$ and the impact of the foreclosure shock on the low-income population in Neighborhood A depends on the magnitude of k^L, which is a parameter that characterizes the elasticity of low-income housing supply in the model. Note that as k_L gets larger, the new construction supply curve for low-income housing becomes less elastic in both neighborhoods. This reduction in supply elasticity increases the extent to which foreclosure-related disamenities are capitalized into housing values. Our model thus predicts that when foreclosures reduce amenity levels and the elasticity of supply of low-income housing is sufficiently low, the "pull" effect of lower prices dominates the "push" effect of reduced amenities, resulting in a net increase in the concentration of low-income residents in Neighborhood A.

Turning to the high-income households, we have

$$\frac{\partial N^{*HA}}{\partial F_A^H} = \frac{(\beta_A - k^H)N^H s_H}{2(1 + k^H N^H s_H)}$$

In the high-income market, there are two opposing effects from the foreclosure shock. First, an increase in foreclosure activity potentially reduces amenity levels in Neighborhood A, reducing the high-income household demand for housing in Neighborhood A. Second, foreclosures reduce the stock of high-income housing in Neighborhood A. If there are no foreclosure spillovers ($\beta_A = 0$), then the foreclosure shock is simply a negative supply shock to the high-income housing market in Neighborhood A; this shock drives up prices and reduces the fraction of high-income households that reside in the neighborhood. If foreclosures reduce neighborhood amenities ($\beta_A < 0$), then an increase in foreclosure activity in Neighborhood A simultaneously reduces demand and the stock of high-income housing in Neighborhood A; while the net impact on the prices in this case depends on the strength of the foreclosure spillovers and the magnitude of k^H, our model unambiguously predicts that a foreclosure shock in Neighborhood A results in a net outflow of high-income residents from Neighborhood A to Neighborhood B.[17,18,19]

2.2. Implications for segregation

Our model predicts that the impact of a foreclosure shock on segregation will depend on the neighborhood in which the shock occurs. To see why this is the case, consider an example where high-income households are concentrated in Neighborhood A and low-income households are concentrated in Neighborhood B. As noted above, the foreclosure shock in Neighborhood A results in high-income households being reallocated from Neighborhood A to Neighborhood B, while low-income households are reallocated from Neighborhood B to Neighborhood A. The net result of this process is a lower concentration of high-income households in Neighborhood A and a lower concentration of low-income households in Neighborhood B. Because minority households are overrepresented in the low-income population, our model predicts that foreclosures in predominantly white areas should reduce racial segregation.

Now say that low-income households are concentrated in Neighborhood A and high-income households are concentrated in

[16] The goal of our theoretical model is to generate testable predictions about the impact of foreclosure shocks on the equilibrium distribution of households across neighborhoods in a school district at a given point in time. While our model is technically dynamic in the sense that there are two time periods, the first time period serves solely as a modeling device for introducing the foreclosure shock. Our model is thus effectively a static general equilibrium model in the spirit of Roback (1982) and Moretti (2013). As is common in such models, we have assumed that the number of households is fixed; this assumption is admittedly at odds with the growth in the number of households in Florida over the course of our sample.

[17] Because $(\beta_A - k^H)$ is negative, $\frac{\partial N^{*HA}}{\partial F_A^H} < 0$.

[18] In our conceptual model, households are allowed to relocate within a district in response to the foreclosure shock, but they are not allowed to leave the district. This closed city assumption simplifies the modeling, but in practice, foreclosures may not only induce movement within a school district but also movement between districts. Our closed city assumption does, however, have some empirical grounding. First, school district boundaries in Florida are coterminous with those of the counties. School districts in Florida are thus spatially very large, and the large size of the school districts increases the likelihood that, conditional on having relocated, households remain within the same school district. Second, in an analysis of post-foreclosure moving behavior, Molloy and Shan (2013) found that 66 percent of households that moved after experiencing a foreclosure relocated within the county.

[19] Our model abstracts away from a household's decision on whether to send its children to public or private schools. It could be the case, however, that households responded to foreclosure shocks by sending their children to private schools. Data from the Florida Department of Education indicate that roughly 90 percent of K-12 students in Florida were enrolled in public schools in every year in our sample; at least in the aggregate, the data do not suggest that substituting private for public education was a common response to foreclosure shocks.

Neighborhood *B*. Our model predicts that the foreclosure shock to Neighborhood *A* will increase the fraction of low-income households in Neighborhood *A* while reducing the fraction of high-income households that live in Neighborhood *A*. Thus, when foreclosures occur in the low-income neighborhood, our comparative statics results imply that the foreclosure shock will increase socioeconomic segregation; because of the strong relationship between race and socioeconomic status, this finding implies that foreclosure activity in minority neighborhoods should increase racial segregation.

Our conceptual framework suggests that estimating the net impact of the foreclosure crisis on segregation necessitates partitioning school districts so that we can measure intra-district changes in the spatial distribution of different types of housing units. To that end, we divide each school district into a "white area" and a "black area" based on district and school-level demographic characteristics. Specifically, we classify schools as being in the black area of the school district if the ratio of black to white students in the school is higher than the ratio of black to white students in the district; otherwise, a school is assigned to the white area.[20]

3. Literature review

To our knowledge, no study has directly examined the impact of the foreclosure crisis on school segregation. There is, however, an extensive literature investigating the impact of foreclosures on a wide number of outcomes. Several of these analyses are germane to our analysis. Two studies of particular interest investigated the relationship between foreclosure activity and residential segregation; because of the close relationship between residential and school segregation (Frankenberg, 2013), these two studies provide indirect evidence of the effect of the foreclosures on school segregation.[21] Ouazad and Rancière (2016) explore the effects of changes in lending standards on residential segregation within metropolitan areas. The study's primary finding is that the mortgage credit expansion during the housing boom enabled white households to leave predominantly black neighborhoods, increasing segregation. In a robustness check, however, the authors also find that foreclosures decreased residential segregation, a finding consistent with our own. Hall et al. (2015) study the relationship between foreclosure rates and the racial composition of neighborhoods and find that foreclosures decrease a neighborhood's white household population while increasing a neighborhood's black population.[22] The results of a simulation exercise lead the authors to conclude that the foreclosure crisis increased residential segregation in the U.S.; this conclusion is at odds with both our findings as well as those of Ouazad and Rancière (2016).[23]

In addition to the work that analyzes measures of residential segregation directly, studies of how access to credit, neighborhood choice, and tenure choice were influenced by foreclosure are also relevant for our analysis as these outcomes are what ultimately determines measures of segregation. Brevoort and Cooper (2013) use consumer credit records to document that borrowers' credit scores recover very slowly after foreclosure, a result the authors attribute to delinquencies on non-mortgage debt in the years following foreclosure. As credit scores are a key component of the mortgage underwriting process, this result implies that households that lost their homes to foreclosure will generally be relegated to living in rental units in the immediate aftermath of mortgage default. In light of the higher delinquency levels among minority borrowers during the crisis (Li and Mayock, 2017; Brevoort and Cooper, 2013) results suggest that credit would be tighter for minority households during the recovery. Faber (2017) confirms this expectation, documenting that the minority households applying for mortgages in 2014 were significantly less likely than white households to be approved for a loan.

Regarding relocation decisions following foreclosure, Been et al. (2011) use student-level records from New York City that were linked to foreclosure data to study the impact of foreclosure on the movement of children between schools. They found that living at an address associated with a foreclosure significantly increased the likelihood that a child changed schools. As the public school that a student attends in New York City is determined primarily by the student's residential location, this finding implies that foreclosures frequently resulted in parents moving into another school attendance boundary. Importantly, the authors found that the students that changed schools because of a foreclosure generally moved to schools where peers exhibited lower proficiency on math and reading examinations relative to peers at the school that the student attended before the foreclosure.

To summarize, while the existing literature has not directly investigated the impact of the foreclosure crisis on school segregation, previous work has addressed the link between foreclosures and residential segregation; the results of these studies are mixed. Minority households were more likely to experience mortgage default during the recent crisis. Other work found that households that experienced foreclosure were more likely to move to a different school attendance zone, and such moves were generally to schools with lower pass rates on standardized tests. The higher racial incidence of default thus implies that minority students were more likely to experience a foreclosure-driven relocation to a lower-performing school.

4. Data

4.1. Data sources and variable construction

Our empirical models express segregation indices as a function of measures of foreclosure activity and the distribution of different types of housing units across predominantly white and predominantly black school attendance zones (SAZ). The primary source for our housing data is a collection of tax assessment records from the Florida Department of Revenue (FDOR). The FDOR data reports the location, property type (e.g., single-family unit, multi-family unit), and estimated market value for all real property in Florida. Given the well-known homeownership gap between black and white households in the U.S., we expect changes in the stock of rental units to have a stronger impact on the location decisions of black households than changes in the stock of owner-occupied units. To allow for this possibility, our empirical specifications include measures of the housing stock that are broken down by both affordability status and tenure status. To construct these tenure-specific housing stock measures, we leverage fields in the FDOR data that report whether or not a homestead exemption was filed on a property as of January 1st in a given year; these exemption fields were used to classify homes as owner-occupied

[20] The delineation of these areas is discussed in detail below.

[21] Frankenberg (2013) finds that the relationship between residential and school segregation to be weaker in Florida than in other states, a finding attributed to the fact that Florida school districts have a common boundary with counties, making them comparatively large in area and less politically fragmented.

[22] Specifically, Hall et al. (2015) estimated the relationship between foreclosure rates and the fraction of white and black households living in Census block groups.

[23] One possible difference between our analysis and that of Hall et al. (2015) that may account for the difference in results is that we define a foreclosure as an REO, while they use a broader definition of a foreclosure, including a listing for public auction. Other than becoming a REO, the other potential outcome of a public auction listing is that the bank that holds the defaulting mortgage is outbid by a third party at the foreclosure auction. In such a case, the foreclosed home never enters REO status and instead transfers directly from the defaulting borrower to another homeowner; we do not include such transfers in our foreclosure measure. The difference in results may also be due to the fact that we control for changes in all housing types and not just REOs in our regressions relating REOs to levels of segregation, while Hall et al. (2015) implicitly assume that other than foreclosures the neighborhood built environment remains the same. Since changes to the built environment other than foreclosures can also induce racial resorting across neighborhoods and may be correlated with new foreclosures, we believe that it is important to control for these changes to mitigate the possibility of omitted variable bias.

or non-owner-occupied.[24] We link the FDOR data to property records from DataQuick that can be used to identify foreclosure completions and the transition of foreclosed homes out of bank-owned status.[25]

After using the FDOR data to construct a parcel-level panel, we use fields reporting the geographic coordinates of each property to assign each property to an elementary school SAZ using digitized maps.[26] For this portion of the data processing, we relied primarily on 2013 maps provided by the National Center for Educational Statistics (NCES). These maps cover 58 of Florida's 67 school districts.[27] We used the NCES maps to identify school districts with open-enrollment student assignment policies and small school districts that had only a single elementary school; because our hypotheses are only relevant in school districts with "neighborhood school" student assignment plans that generate a one-to-one relationship between a household's location and the assigned public elementary school, the open-enrollment and single-school districts were removed from our sample. A set of 2011-vintage SAZ maps from Maponics was used to add an additional 3 districts to the panel.

After linking the FDOR and DataQuick data and assigning properties to SAZs, we have a parcel-level panel that identifies the market value, foreclosure and post-foreclosure status, owner-occupancy status, and structure type of all residential properties in 39 Florida school districts between 1998 and 2013. We collapse this parcel-level data to construct six housing stock measures at the SAZ-year level: completed foreclosures, recent REO single-family homes, condominiums, mobile homes, apartments, and single-family homes that are not recent REOs. We focus on single-family foreclosures and recent REOs because, given their size, these are the housing units that are most likely to be inhabited with families with children.[28]

We should emphasize here that our foreclosure variables represent *completed* foreclosures and not foreclosure *starts*. Specifically, we define a foreclosure completion as the repossession of home by a bank or a financial institution, in which case the property enters Real Estate Owned (REO) status. Because they are not expected to produce the same types of externalities as REO properties, we exclude from our measure completed foreclosures that resulted in a third party taking possession of the defaulting borrower's home at the foreclosure auction. A recent REO home is defined as a property that exited REO status in the previous year.

With the exception of the foreclosure variable, all housing stock measures are divided into subcategories based on whether or not the home is classified as "affordable" and whether or not the property is owner-occupied. A housing unit is classified as affordable if its estimated monthly rent is less than the fair market rent for a two-bedroom housing unit as reported by the Department of Housing and Urban Development; otherwise, the housing unit is classified as "unaffordable."[29] Note that the affordability designation is made for each home for each year in our panel; hence, a property may transition between affordability classifications over the course of our panel. We classify a housing unit as owner-occupied in a given year if the owner filed for a property tax homestead exemption in that year. If no such exemption is filed, the home is classified as a rental unit in that year. Florida law dictates that the homestead exemption can only be applied to primary residences. Because the homestead exemption provides significant tax savings, we are confident in categorizing homes with the exemption as owner-occupied. Homes without the exemption are either rentals or second homes. The fraction of single-family homes that are second homes is expected to be small because in Florida most vacation homes are condominiums. For condominiums we cannot rule out the possibility that a substantial number of the properties we label as rentals may in fact be second homes not available for rent.

For each SAZ in the housing panel, we merged in information on the school's racial makeup from the Common Core Data complied by NCES. The Common Core data reports the numbers of non-Hispanic white, black, Hispanic, Asian, and American Indian students attending each school. We utilize these student demographic measures for two purposes: classifying a school as belonging to the white or black portion of the school district and constructing a series of segregation measures. To construct the school racial classification, we first restrict the NCES data to the set of elementary schools for which we have calculated the housing stock measures. Let i index schools, j index school districts, and t index years. Let $\%Black_{ijt}$ and $\%Black_{jt}$ denote the number of black students relative to the sum of black and white at the school and district level, respectively.[30,31]

In each time period, we use $\%Black_{ijt}$ and $\%Black_{jt}$ to construct an indicator variable (A_{ijt}) that is equal to one if a school is classified as

[24] The FDOR data reports tenure status as of January 1st of a given year. For example, the 2005 count of owner-occupied single-family units in a county is defined as the number of single-family homes covered by a homestead exemption as of January 1st of 2005. The DataQuick data reports the exact date on which properties enter into and exit from REO status. To align our foreclosure variables with the data derived from the FDOR files, we classify a home as an REO if it was in REO status as of January 1st of that year. A recent REO is then defined as a property that was in REO status as of January 1st of the previous year but was not in REO status as of January 1st of the current year.

[25] The algorithm used to identify current and past foreclosures with these data is described in Ihlanfeldt and Mayock (2016a).

[26] For a given residential location, our operational definition of an elementary school is the school that a child at that location is assigned to attend in third grade.

[27] In Florida districts and counties have identical boundaries. The districts excluded from the NCES map are all small, rural counties.

[28] An additional consideration that drove our focus on single-family units was data-driven. While we were able to verify that DataQuick's distressed sale transaction can effectively identify when single-family units enter and exit the REO stock, we were not confident that this field could be used to quantify foreclosure activity on condominiums and multi-family properties. Specifically, when attempting to construct REO measures for the condominium and multi-family stock, we discovered that the distressed sale variable could not be used to differentiate between failed development projects in which the lender foreclosed on common grounds still owned by the developer and standard foreclosures in which a homeowner defaulted on a residential mortgage. Because of the large number of failed condominium developments that occurred during the downturn, this data limitation appeared to result in a very significant overestimate of the REO and recent REO stock in several markets.

[29] Monthly rent is estimated by multiplying an area's rent to price ratio by the unit's estimated market value. Rent-to-price ratios were calculated for 11 market areas covering the state for each year of our panel using PUMS data from the American Community Survey. The rent reported for single-family rentals was regressed on variables describing the size and quality of the home. The results from these regressions were used to predict the rents of owner-occupied single-family homes. The predicted rent was then divided by the owner's estimate of market value to obtain the rent to price ratio. These ratios were averaged over all of the sampled properties found within a market area to obtain the area's rent-to-price ratio. For each property in our sample, we multiply this ratio by the property's estimated market value as reported in the FDOR data; this market value estimate is defined by law as the estimated price that the home would fetch in an arm's length transaction on January 1^{st} of the reporting year. Finally, a property is classified as "affordable" if the estimated rent for that property was less than the fair market rent for two-bedroom housing units reported by the Department of Housing and Urban Development.

[30] Note that because we are interested in the segregation of white and black students, these percentage measures do not include students of other races.

[31] If B_{ijt} and W_{ijt} denote the count of black and white students in school i, respectively, then $\%Black_{ijt}$ is defined mathematically as

$$\%Black_{ijt} = \frac{B_{ijt}}{B_{ijt} + W_{ijt}}$$

Now let B_{jt} denote the total number of black students in all elementary schools in district j in year t, and define W_{jt} similarly for white students. If J is the set of all elementary schools in district j, then

$$B_{jt} = {}_{i \in J}\ B_{ijt}$$

$$W_{jt} = {}_{i \in J}\ W_{ijt}$$

and the relative prevalence of black students at the district level in a given year is defined as

$$\%Black_{jt} = \frac{B_{jt}}{W_{jt} + B_{jt}}$$

belonging to the black portion of the school district and is zero otherwise. Specifically,

$$A_{ijt} = \begin{cases} 1 & \text{if } \%Black_{ijt} \geq \%Black_{jt} \\ 0 & \text{if } \%Black_{ijt} < \%Black_{jt} \end{cases} \tag{1}$$

In what follows, schools for which $A_{ijt} = 0$ are said to be in the white area of the school district. Note that the white and black areas are defined on a year-by-year basis; hence, it is possible for a particular SAZ to be in the white area one year and in the black area in another year.

A_{ijt} is used to construct measures of the district's housing stock that are located in the white and black areas for each period in the sample. If k indexes the different housing supply measures and H_{ijtk} denotes an arbitrary measure of the housing stock of type k (e.g., affordable single-family rental units, foreclosures) located in school i's SAZ in period t, then the supply of type-k housing in the black area in school district j in period t is defined as

$$H_{Bjtk} =_{i \in J} A_{ijt} H_{ijtk} \tag{2}$$

and the supply of type-k homes in the white area of district j is

$$H_{Wjtk} =_{i \in J} (1 - A_{ijt}) H_{ijtk} \tag{3}$$

After constructing the aforementioned housing measures, we use the NCES data for the same set of elementary schools to calculate five alternative measures of black-white segregation for elementary schools: the dissimilarity index, the exposure index of whites to blacks ("White-Black Exposure Index"), the exposure index of blacks to whites ("Black-White Exposure Index"), the white isolation index, and the black isolation index. The formula for each index can be found in Appendix A.

The dissimilarity index measures racial balance across schools within the district. If black students are distributed evenly across all elementary schools, the dissimilarity index takes a value of zero and there is no segregation. At the opposite extreme, the index assumes a value of unity when black and white students are completely segregated into separate schools. The exposure indices measure potential contact or the possibility of interaction between whites and blacks. These indices are of particular relevance in the context of peer group effects, which have been found to have an important influence on student success (Epple and Romano, 2011). The isolation indices measure the extent to which blacks (whites) are exposed only to other blacks (whites) and not to any other racial group.[32] The exposure and isolation indices both range between 0 and 1. Lower values of the exposure index are indicative of higher levels of segregation, while higher levels of the isolation index are indicative of lower levels of segregation. It should be noted that the dissimilarity index simply reflects the distribution of students of different races across schools; this index is not directly affected by the racial composition of the school district. The exposure and isolation indices, in contrast, are functions of the relative prevalence of black and white students in the school district as well the distribution of students across schools within the district.

4.2. Descriptive statistics

Means and standard deviations for select years in our sample are reported in Table 1. The statistics reported specifically for the black and white portions of the school districts are constructed using the definitions described in Section 4. 1998 and 2013 are the first and last years of our panel, respectively, 2000 roughly coincides with the beginning of extreme home price appreciation in Florida, 2005 is near the peak of the most recent housing cycle in several of the markets in our study, and 2010 is near the trough of the most recent cycle.

Over the course of our panel, the dissimilarity and exposure indices suggest that segregation in Florida elementary schools increased over time. The UCLA Civil Rights Project attributes this increase, which is generally true across all southern states, as the result of the recension of federal integration orders over the last two decades (Orfield et al., 2016).

In contrast, the black and white isolation indices indicate that these groups have become less racially isolated. The differences between the isolation index dynamics and those of the dissimilarity and exposure indices can be reconciled by noting that the dissimilarity and exposure indices are constructed using only the black and white student populations, while the isolation indices measure black (white) isolation from all other groups, including Hispanics. Because the Hispanic student population has grown so rapidly in Florida (72.8 percent over the years covered by our panel), both white and black students are in schools with greater numbers of Hispanic students, resulting in less

Table 1
Means and Standard Deviations of Key Variables in Selected Years.

	Year				
	1998	2000	2005	2010	2013
Dissimilarity Index[a]	0.397	0.402	0.409	0.411	0.416
	(.176)[b]	(.178)	(.161)	(.154)	(.150)
White-Black Exposure Index	0.159	0.156	0.149	0.151	0.152
	(.086)	(.085)	(.095)	(.087)	(.087)
Black-White Exposure Index	0.562	0.541	0.507	0.459	0.446
	(.187)	(.195)	(.205)	(.193)	(.196)
White Isolation Index	0.731	0.719	0.68	0.601	0.584
	(.135)	(.141)	(.147)	(.129)	(.133)
Black Isolation Index	0.321	0.326	0.313	0.303	0.301
	(.170)	(.178)	(.188)	(.186)	(.186)
Recent REO Rental					
White Area: Affordable[c,e]	2.6	17.17	19.9	118.92	117.02
	(4.43)	(22.01)	(22.77)	(131.43)	(125.81)
White Area: Unaffordable	0.87	6.95	14.45	62.62	97.1
	(2.41)	(13.25)	(17.59)	(82.37)	(143.48)
Black Area: Affordable[d]	3.97	31.72	53.85	199.67	203.17
	(7.11)	(53.60)	(81.19)	(273.60)	(292.31)
Black Area: Unaffordable	0.62	2.9	10.32	23.2	39
	(1.64)	(3.83)	(18.53)	(24.58)	(52.04)
Recent REO Owner-Occupied					
White Area: Affordable	4.82	26.02	16.45	108.75	61.32
	(11.24)	(36.68)	(21.11)	(142.81)	(80.25)
White Area: Unaffordable	2.2	14.75	23.77	97.45	95.15
	(4.83)	(27.31)	(32.22)	(143.97)	(143.33)
Black Area: Affordable	5.15	34.95	29.42	124.9	75.5
	(10.87)	(56.44)	(40.99)	(195.20)	(105.81)
Black Area: Unaffordable	1.65	5.57	12.15	32.15	36.85
	(3.12)	(7.58)	(16.03)	(36.59)	(52.35)
Foreclosures					
White Area	139.32	123.85	126.12	994.4	889.87
	(213.69)	(184.00)	(181.68)	(1205.00)	(942.15)
Black Area	163.15	150.75	201.97	876.72	798.37
	(270.58)	(242.42)	(269.44)	(1121.49)	(927.47)

[a] See Appendix A for definitions of segregation measures.
[b] Standard deviations in parentheses.
[c] The white area in school district j is the set of schools that satisfy $\%Black_{ijt} < \%Black_{jt}$
[d] The black area in school district j is the set of schools that satisfy $\%Black_{ijt} \geq \%Black_{jt}$
[e] Units with estimated rents that are below the fair market rent for a two-bedroom unit reported by the Department of Housing Development are classified as affordable units. Units with rents that exceed this limit are classified as unaffordable. See the text for details on the estimation of the unit rents.

[32] To be clear, the isolation index measures black (white) isolation from all students who are not black (white) and not just isolation from whites (blacks).

isolation from these students.[33]

The means for single-family foreclosures show that in the years prior to the housing market crash, foreclosures were relatively rare in both the black and white portions of the schools districts in our sample. Between 2005 and 2010, however, foreclosure activity skyrocketed. Within the white areas, the average number of foreclosures increased by roughly 689% over this period. At 334%, the increase in foreclosure completions in the black area, while much smaller than that seen in the white areas, was still unprecedented.[34]

Following the completion of the foreclosure process, most properties are generally repossessed by the bank, entering REO status; it is relatively rare for a home to be transferred to a third-party buyer at the foreclosure auction.[35] The REO properties are then sold by financial institutions to either owner-occupants or investors, and previous research has found that most investor-acquired properties are offered for rent, as opposed to being held for speculation purposes (Ellen et al., 2012; Immergluck, 2012).

In both white and black areas, we see that the average number of recent REO properties, regardless of tenure, grew in the years leading up to the crash, albeit modestly. Unsurprisingly, between 2005 and 2010, the stock of recent REO homes experienced incredible growth ranging from 130 to 581 percent depending on area, tenure, and affordability. The largest changes in the recent REO stock occurred for affordable units in white areas, where rental and owner-occupied units increased 495 percent and 581 percent, respectively. These large changes in foreclosure activity are of critical importance for the identification of our empirical models. If the probability that a borrower defaults on a mortgage is independent of the move propensity of other households within a school district, then changes in the composition of the housing stock due to foreclosure activity provide exogenous variation that can be used to test how changes in the spatial distribution of different types of housing impact school segregation.

5. Methodology

Because our dependent variables are bounded in the unit interval, we utilize a generalized linear model (GLM) that imposes this constraint in the estimation process. Specifically, we adopt the pooled fractional Probit (PFP) model of Papke and Wooldridge (2008). An advantage of the PFP model over other models in the GLM family is that it allows us to account for time-invariant heterogeneity across school districts that is potentially correlated with the covariates in the model.[36]

In the absence of instrumental variables, identification of the PFP model requires that, conditional on school district fixed effects, the regressors must be strictly exogenous. This assumption is similar to the identification condition employed in most empirical work with linear panel data models. While the strict exogeneity assumption allows for the regressors to be correlated with time-invariant district-level heterogeneity, this assumption requires that the regressors be uncorrelated with time-varying unobservables in all time periods. That is, in addition to ruling out contemporaneous correlation between the regressors and unobservables, the strict exogeneity assumption also requires that there be no feedback effects between unobservables and future or past values of the covariates. Wooldridge (2010) suggests testing for feedback effects by including leading values of the regressors that are suspected to be endogenous in the estimating equation and conducting an F-test robust to serial correlation and heteroskedasticity on the lead terms. We used this approach to test for the presence of feedback effects between unobservable factors driving school segregation and foreclosure activity for each of the segregation measures that we analyze. For the dissimilarity index, the black isolation index, and the black-white exposure index, the p-value for the joint significance test of the lead terms was in excess of 10 percent. For these three segregation measures, we thus cannot reject the null that there are no feedback effects between unobservables and our foreclosure variables. For the white isolation index and white-black exposure index models, however, we rejected the null of no feedback effects at the 5 percent level. The results that use these two measures of segregation should thus be viewed with caution.[37]

Before proceeding, we introduce some notation to simplify the display of the empirical models. Let

$$J = \{\text{Owner-Occupied,Renter-Occupied}\}$$
$$A = \{\text{Black Area,White Area}\}$$
$$C = \{\text{Affordable,Unaffordable}\}$$

and define Q as the cross product of these three sets[38,39]

$$Q = J \times A \times C$$

For an arbitrary variable Y_{it}, define the district-specific intertemporal mean as

$$\overline{Y}_i = \frac{1}{T}{}_{t=1}^{T} Y_{it}$$

where i indexes the N different school districts and t indexes years. Finally, define the variables that enter the model as follows[40]

X_{qit}	Recent REO single-family units	C_{qit}	Vector of control variables
F_{ait}	Foreclosure	θ_t	Year fixed effects
S_{it}	Segregation measure		
$\Phi()$	Standard normal cumulative distribution function		

where a indexes A and q indexes Q.

The estimating equation for the PFP model can now be written as

$$E[S_{it}|Z_{it}] = \Phi\Big(\theta_t +_{q\in Q} \beta_q X_{qit} +_{q\in Q} \alpha_q \overline{X}_{qi} +_{a\in A} \gamma_a F_{ait} +_{a\in A} \gamma_a \overline{F}_{ai} + C_{qit}\psi +_{q\in Q} \tau_q \overline{C}_{qi}\Big) \tag{4}$$

where Z_{it} is a vector that is a collection of all variables included on the right-hand side of Eq. (4). Following Papke and Wooldridge (2008), we estimate the parameters of Eq. (4) by maximizing the Probit log-likelihood function constructed using the pooled data.

[33] Clotfelter et al. (2006) find more generally for southern school districts that the growth in the Hispanic school population explains the divergence in trends between isolation and the other segregation indices.

[34] In 2005, there were 126 foreclosures in the white area relative to 202 foreclosures in the black area. Some of the dramatic percentage increase in foreclosure activity in the white area relative to the black area between 2005 and 2010 is thus attributable to a lower base of foreclosures in the white area in 2005.

[35] The other potential outcome of a completed foreclosure is that the bank that holds the defaulting mortgage is outbid by a third party at the foreclosure auction. In such a case, the foreclosed home never enters REO status and instead transfers directly from the defaulting borrower to another homeowner; we do not include such transfers in our foreclosure measure.

[36] Researchers commonly include dummy variables defined at the unit of observation in non-linear panel models in an attempt to control for unit-specific heterogeneity that could potentially introduce bias. As noted by Papke and Wooldridge (2008), however, in short (or "small T") panels this approach suffers from an incidental parameters problem, rendering the estimator inconsistent.

[37] As discussed in Papke and Wooldridge (2008), the PFP model can still be identified when the strict exogeneity assumption does not hold. Identification in such cases, however, requires the use of instrumental variables. Unfortunately, we were not able to identify variables that could serve as instruments.

[38] To ensure the exogeneity of our area assignments, each SAZ is assigned an area based upon the value of percent black in year $t-1$.

[39] An element of this set would include, for instance, an owner-occupied property in the black portion of the school district that was classified as unaffordable.

[40] The control variables that we include in the model are: non-recent-REO single-family homes, condominiums, and mobile homes by area (black/white), affordability status (affordable/unaffordable), and tenure (renter-occupied versus owner-occupied). Because our multi-family units are only renter-occupied by definition, multi-family units only enter by area and affordability status.

Table 2
Estimated effects of recent REOs on measures of school segregation.

	Dependent Variable				
	Dissimilarity Index[a]	White-Black Exposure	Black-White Exposure	White Isolation	Black Isolation
	Recent REO[b], Renter-Occupied[c] White Area[d]				
Affordable[f]	−.39428**	0.1647	−.10223	−.39741***	−.14622
	(.20139)[g]	(0.14846)	(0.12884)	(0.153)	(0.11172)
	[−.13744][h]	[.03499]	[−.03441]	[−.12914]	[−.04361]
Unaffordable	0.05446	−.12902	−.05372	0.18979	0.09105
	(0.24808)	(0.22775)	(0.22366)	(0.2209)	(0.22728)
	[.01898]	[−.02741]	[−.01808]	[.06167]	[.02716]
	Recent REO, Renter-Occupied: Black Area[e]				
Affordable	.21699*	−.01228	−.05757	0.08466	.17621**
	(0.11516)	(0.04213)	(0.0905)	(0.07008)	(0.08852)
	[.07564]	[−.00261]	[−.01937]	[.02751]	[.05255]
Unaffordable	−1.00895**	.82285***	−.67409**	−.69669***	0.26992
	-0.44991	-0.29382	-0.31378	-0.2533	-0.33976
	[−.35171]	[.17481]	[−.22687]	[−.22639]	[.08050]
	Recent REO, Owner-Occupied: White Area				
Affordable	0.16436	−.10345	0.23425	.48653**	0.17176
	(0.36505)	(0.20055)	(0.30535)	(0.23927)	(0.19294)
	[.05730]	[−.02198]	[.07884]	[.15810]	[.05123]
Unaffordable	0.32165	−.21706*	0.30785	.36777**	−.00247
	(0.251)	(0.11181)	(0.19932)	(0.1559)	(0.173)
	[.11213]	[−.04611]	[.10361]	[.11951]	[−.00074]
	Recent REO, Owner-Occupied: Black Area				
Affordable	−.24749	0.01022	−.19907	−.34370**	−.25937
	(0.28109)	(0.13292)	(0.20378)	(0.16081)	(0.17123)
	[−.08627]	[.00217]	[−.06700]	[−.11169]	[−.07736]
Unaffordable	−.44867	0.04069	0.09268	−.59335	−.47943
	(0.63703)	(0.26174)	(0.38166)	(0.36204)	(0.43164)
	[−.15640]	[.00864]	[.03119]	[−.19281]	[−.14299]
Observations	618	618	618	618	618

All housing stock variables are measured in 1000 s of units.
Model includes controls for stock of single-family units, condominiums, mobile homes, and multi-family units by area (black/white), affordability status, and tenure status.
*, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.
[a] See Appendix A for definitions of segregation measures.
[b] Recent REO properties are those that transferred out of bank-owned status within the past year.
[c] A property is defined as renter-occupied if the owner did not file a homestead exemption in a given year. Otherwise, the property is classified as owner-occupied.
[d] The white area in school district j is the set of schools that satisfy $\%Black_{ijt} < \%Black_{jt}$
[e] The black area in school district j is the set of schools that satisfy $\%Black_{ijt} \geq \%Black_{jt}$
[f] Units with estimated rents that are below the fair market rent for a two-bedroom unit reported by the Department of Housing Development are classified as affordable units. Units with rents that exceed this limit are classified as unaffordable. See the text for details on the estimation of the unit rents.
[g] Standard error clustered at the district level is in parentheses.
[h] Estimated average partial effect is in brackets.

The estimation of average partial effects is similarly straightforward. For instance, if z_{kit} is an arbitrary element of Z_{it}, and the parameter associated with z_{kit} is denoted Γ_k, then differentiating Eq. (4) with respect to z_{kit} gives us the following partial effect for observation i in period t

$$\frac{\partial E[S_{it}|Z_{it}]}{\partial z_{kit}} = \Gamma_k \phi(Z_{it}) \tag{5}$$

where $\phi()$ denotes the standard normal probability density function. Papke and Wooldridge (2008) show that the average partial effect (APE_k) of z_{kit} on S_{it} can be consistently estimated by simply averaging over all observations of Eq. (5). We thus estimate the average partial effects in our model as

$$APE_k = \frac{\Gamma_k}{NT} \sum_{t=1}^{T} \sum_{i=1}^{N} \phi(Z_{it}) \tag{6}$$

6. Results

Our main results for the segregation models are reported in Table 2 and 3. For each variable, three estimates are reported: the coefficient from the PFP model, the standard error clustered at the school district level, and the APE estimated as in Eq. (6). Turning first to the impact of the post-foreclosure variables summarized in Table 2, we find that the impact of an additional recent REO single-family rental unit in the white portion of the school district on segregation depends on whether the unit is classified as affordable or unaffordable. For unaffordable units, the estimated coefficient is statistically insignificant for all five dependent variables, suggesting that such units have no impact on school segregation. In contrast, for four of the five segregation measures, affordable single-family recent REO rental units are shown to decrease segregation, with statistically significant effects registering for the dissimilarity and white isolation measures.

These findings suggest that it was only the lower-cost recent REO single-family rentals in white areas that offered new housing opportunities to black families. Our theoretical model predicted that black households would move from the black to the white area because the recent REO rental units lower the price differential between the white and black areas and the rentals provide entry into the white area by black families who cannot afford to purchase a home. Apparently, the unaffordable rental units do not produce spillover effects large enough to induce a move by blacks from the black to the white area.

In the black portion of the school district, we again find that the effect of an increase in the recent REO single-family rental stock depends on affordability. For affordable units, all of the signs on the estimated coefficients support the claim that “REO-to-rental” conver-

Table 3
Estimated Effects of Foreclosures on Measures of School Segregation.

	Dependent Variable				
	Dissimilarity Index[a]	White Exposure	Black Exposure	White Isolation	Black Isolation
	Foreclosures: White Area[c]				
	−.10179***	.04222*	.05191**	−.03895	−.05775***
	(0.03842)[e]	(0.02315)	(0.02481)	(0.02617)	(0.01744)
	[−.03548][f]	[.00897]	[.01747]	[−.01266]	[−.01722]
	Foreclosures: Black Area[d]				
	.08731**	−.02052	−.06247***	0.02677	.05955***
	(0.04227)	(0.02113)	(0.02376)	(0.02515)	(0.02102)
	[.03043]	[−.00436]	[−.02103]	[.00870]	[.01776]
Observations	618	618	618	618	618
Year	**Total Effect**[g]				
1998	0.405	0.133	0.505	0.683	0.285
2000	0.404	0.132	0.504	0.683	0.284
2005	0.404	0.133	0.501	0.681	0.286
2010	0.388	0.137	0.501	0.675	0.283
2013	.386††	.139†††	0.495	.671††	0.287
Year	**Recent REO Effect**[b, h]				
1998	0.402	0.135	0.505	0.681	0.284
2000	0.4	0.134	0.504	0.681	0.284
2005	0.399	0.135	0.502	0.678	0.285
2010	0.395	0.134	0.501	0.679	0.285
2013	.390†	0.137	0.495	.674†	0.288
Year	**Foreclosures Effect**[i]				
1998	0.4	0.133	0.502	0.68	0.286
2000	0.401	0.133	0.502	0.68	0.286
2005	0.402	0.133	0.5	0.681	0.287
2010	0.391	0.138	0.501	0.675	0.283
2013	.392††	.137††	0.501	0.676	0.284

All housing stock variables are measured in 1000 s of units.
Model includes controls for stock of single-family units, condominiums, mobile homes, and multi-family units by area (black/white), affordability status, and tenure status.
*, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. †, ††, ††† indicate that the predicted 2013 index value is significantly different from the 2005 value at the 10%, 5%, and 1% levels, respectively.
[a] See Appendix A for definitions of segregation measures.
[b] Recent REO properties are those that transferred out of bank-owned status within the past year.
[c] The white area in school district j is the set of schools that satisfy $\%Black_{ijt} < \%Black_{jt}$
[d] The black area in school district j is the set of schools that satisfy $\%Black_{ijt} \geq \%Black_{jt}$
[e] Standard error clustered at the district level is in parentheses.
[f] Estimated average partial effect is in brackets.
[g] Total Effect is the prediction of the index given the mean values of the recent REO properties and foreclosures for the designated year, holding all other variables constant at their sample means.
[h] Recent REO Effect is the prediction of the index given the means values of the recent REO properties for the designated year, holding all other variables (including foreclosures) constant at their sample means.
[i] Foreclosures Effect is the prediction of the index given the mean values of REO starts for the designated year, holding all other variables (including the recent REO properties) constant at their sample means.

sions in black neighborhoods increase segregation, with the effects statistically significant for the dissimilarity and black isolation indices and just marginally insignificant for the white isolation index. These results are consistent with the idea that an increase in the availability of these single-family rentals in the black area keeps some black families in the black area who otherwise would have moved to the white area and causes new black families to choose the black area over the white area. For unaffordable units, the results are somewhat mixed but generally suggest a reduction in segregation in response to the surge in higher-end rental properties during the foreclosure crisis. Overall, it appears to be the case that these higher-cost rental properties induced some whites to select the black area over the white area.[41]

Consistent with our expectations, we find little evidence that homes that transition from REO status directly to owner-occupancy had an impact on school segregation. For both the white and the black areas, the coefficients on the owner-occupied recent REO terms in Table 2 are generally statistically insignificant. The lone exceptions to this pattern pertain to the white isolation index: we find that affordable and unaffordable units in the white area have a positive and statistically significant effect on this index, while affordable owner-occupied recent REOs in the black area reduce white isolation. Given racial differences in income and access to credit, white households are more likely to be able to purchase the more expensive owner-occupied units. This finding thus likely reflects mechanisms that drive racial differences in the homeownership rate.

The results in Table 3 offer strong evidence that foreclosures in the white area decreased segregation. The estimated coefficients on the foreclosure variables have signs consistent with foreclosures reducing segregation (as measured by the dissimilarity index), increasing inter-race exposure (as measured by the exposure index) and reducing racial isolation (as measured by the isolation index). In only one case (the white isolation index) was the estimated effect not statistically significant at conventional levels.[42]

As noted above, there are three possible explanations for these results: 1) black families may be moving into the white area to take advantage of lower housing costs, 2) white families may be leaving the white area and moving into the black area in response to a foreclosure-induced decline in the amenity value of their neighborhood and 3) foreclosed upon white homeowners may move from the white to the black area in order to reduce their housing consumption.[43]

The relative importance of black entry versus white exit in explaining the decline in segregation from a foreclosure in the white area cannot be determined from our data. The investigation of this issue requires knowledge on how a foreclosure in the white area affects the location decisions of individual black and white families. The findings of Molloy and Shan (2013), however, can help us shed some light on this issue. They find that households living in homes where foreclosure proceedings had commenced moved to neighborhoods that had racial compositions that were largely similar to the neighborhoods from which they relocated. This finding suggests that the movement of white families in response to a foreclosure in their neighborhood is unlikely to result in a significant change in the number of white students within the white area. We therefore believe that the primary factor accounting for our finding that a foreclosure in the white area reduces segregation is the movement of black families from the black to the white area.

In contrast to the results for foreclosure activity in the white neighborhoods, we find that foreclosures in the black portions of our school districts served to increase racial segregation. Across our five different segregation variables, the signs on the foreclosure variable in the black area were exactly the opposite of what we found in the white

[41] To investigate the possibility that the impact of foreclosures on segregation varied across the housing cycle, we constructed a "post-crash" indicator variable that is equal to

(footnote continued)
one in the years 2007 through 2013 and equal to zero in the years 1998 through 2006. We interacted this post-crash indicator with variables measuring the number of foreclosures and recent REOs in the white and black areas of the school district; we then added these interaction terms to the set of covariates and re-estimated all of our segregation models. Regardless of the measure of school segregation, with few exceptions, the estimated coefficients were not found to be significantly different between the pre-crash and post-crash periods.

[42] A referee raised the concern that many of the schools within the white area may have a student population that is majority Hispanic and that this may have affected our results. The only district where a large percentage of the schools in the white area are majority Hispanic is Miami-Dade County, where 106 of the 113 schools (94 percent) in 2013 are majority Hispanic. For the other districts, 70 percent have no majority Hispanic schools in the white area, while the rest have less than 30 percent majority Hispanic schools. Dropping the Miami-Dade district from our panel had no discernable effect on our major findings.

[43] We are assuming that the relocating white family moves within the district. In Florida this assumption is defensible because school districts and counties have identical boundaries and counties are large in both population and geographic area.

area, with black-area foreclosures increasing the dissimilarity and isolation indexes and reducing the black-white exposure index. The explanation provided by our theoretical model for this finding is that, following the foreclosure shock, black families chose the black over the white area due to the housing cost savings which more than offset any foreclosure-related reduction in neighborhood quality.

Thus far we have focused on how changes in the housing stock in isolation affected district-level measures of school segregation. The foreclosure crisis resulted in large contemporaneous changes in many of our variables, however, so the foregoing discussion says nothing of the total impact of the foreclosure crisis on school segregation.

Because foreclosures and recent REO properties appear to reduce segregation if they are located in white areas but increase segregation if in black areas, it is unclear whether the crisis has had a positive, negative, or neutral effect on school segregation. To investigate the net impact of the foreclosure crisis on segregation, in the lower panel of Table 3 we report Total Effect, Foreclosure Effect, and Recent REO Effect estimates. We construct the Total Effect estimate as follows. First, we calculate the average of all of the control variables across all districts and years in our sample. Call this vector of means $\overline{X}$. Then, we calculate the average values of all of the foreclosure-related variables (foreclosures, and recent REO properties by area, tenure, and affordability status) for each year t in the sample. Call this vector of foreclosure-related means F_t. For each year t in our sample we then set the control variables and foreclosure variables equal to $\overline{X}$ and F_t, respectively, and use the estimated regression models to predict the values of each of the five segregation measures. The estimation of the Recent REO Effects and Foreclosure Effects proceeds similarly; in the former case, all variables (including foreclosures) are held constant at their grand mean while allowing the average recent REO variables to change over time, while in the latter case we hold the recent REOs and control variables constant at their means while allowing the average foreclosure activity to vary over time.

The Total Effect estimates reveal that foreclosures and recent REO properties jointly had little influence on school segregation prior to the housing market crash. Following the housing crash, however, foreclosures and recent REOs caused a reduction in school segregation as measured by the dissimilarity index, white-black exposure index, and the white isolation index. For example, we find that the variation in the foreclosure variables between 2005 and 2013 reduced the dissimilarity index from 0.404 in 2005 to 0.386 in 2013 – a change statistically significant at the 5% level. This decline in the dissimilarity index represents a 4.5 percent average change across all school districts in our sample. This average, however, obscures a significant amount of heterogeneity in the estimated net effect of the foreclosure variables across school districts. To give a sense of the inter-district variation in the total foreclosure effect, we report in Table 4 the results of this prediction exercise conducted on a district-by-district basis. The estimated Total Effect tends to be much larger than the average in the larger school districts. For example, for Hillsborough and Orange counties, two of the largest districts, the percentage reductions in the dissimilarity index are more than twice as large as the average change.

The Recent REO and Foreclosure Effect reported in Table 3 reveal that the relative importance of these effects varies among the segregation measures. For the dissimilarity index, both effects produced statistically significant declines in segregation of roughly the same magnitude. This is also true for the white-black exposure index, though the Recent REO effect in this case is not statistically significant. For the white isolation index, only the Recent REO Effect is statistically significant.

The estimated Total, Recent REO, and Foreclosure Effect are all consistent with the changes in the mean values of the foreclosure crisis variables (reported in Table 1) and the estimated APEs reported in Table 2 and 3. The summary statistics show that the increase in both foreclosures and recent REO rentals was much greater in white than in black areas: between 2005 and 2013, for example, the percentage change in these variables was roughly twice as large in white as in black areas. The estimated APEs imply that a foreclosure or a recent REO rental in the white area reduced segregation by more than a foreclosure or recent REO rental in the black area increased segregation. The greater changes in the crisis variables and their stronger effects within white areas thus explain the reduction in segregation after the crash, despite the effects in black areas that tended to worsen segregation.

All of the estimated segregation models discussed above include variables measuring the stock of multi-family units, condominiums, mobile homes, and single-family homes found within the black and white areas in a school district. With the exception of multi-family units, all of these measures are broken down by affordability status and tenure status (owner-occupied or renter-occupied); because multi-family units in our data are renter-occupied by definition, these variables enter only by area and affordability status. Like the foreclosure variables, these other housing stock measures may affect household location decisions; as these variables are also likely correlated with foreclosure activity, excluding them from our models may result in omitted variables bias. Relative to the foreclosure crisis variables, however, our housing stock control variables have considerably less variation within districts over time. Due to this limited variation, we expect the estimated effects of the control variables to be imprecisely estimated. While our empirical results square with this

Table 4
Estimated Effect of Foreclosure Crisis on Dissimilarity Index by District.

District Name	Dissimilarity Index[a,b] 2005	Dissimilarity Index 2013	Percentage Change	Total Students in 2010
Alachua	0.442	0.428	−3.17	11,681
Bay	0.487	0.482	−1.03	12,716
Brevard	0.438	0.418	−4.57	32,279
Broward	0.639	0.600	−6.10	101,799
Charlotte	0.290	0.267	−7.93	6727
Citrus	0.259	0.249	−3.86	6927
Collier	0.619	0.575	−7.11	20,863
Columbia	0.386	0.384	−0.52	5006
Dade	0.777	0.779	0.26	153,481
DeSoto	0.130	0.130	0.00	2372
Duval	0.499	0.469	−6.01	57,810
Escambia	0.452	0.443	−1.99	17,924
Flagler	0.161	0.153	−4.97	6251
Glades	0.451	0.45	−0.22	809
Hamilton	0.255	0.255	0	1017
Hernando	0.23	0.21	−8.70	9348
Highlands	0.191	0.18	−5.76	5334
Hillsborough	0.566	0.501	−11.48	85,960
Indian River	0.180	0.174	−3.33	5031
Lake	0.406	0.391	−3.69	17,734
Leon	0.536	0.542	1.12	15,905
Levy	0.300	0.297	−1.00	2261
Madison	0.399	0.400	0.25	1837
Manatee	0.480	0.474	−1.25	18,684
Marion	0.391	0.377	−3.58	19,101
Martin	0.541	0.533	−1.48	7654
Okaloosa	0.325	0.322	−0.92	12,976
Okeechobee	0.119	0.120	0.840	2920
Orange	0.613	0.553	−9.79	81,036
Osceola	0.514	0.492	−4.28	23,954
Palm Beach	0.670	0.630	−5.97	73,241
Pasco	0.428	0.363	−15.19	29,214
Pinellas	0.400	0.340	−15.00	40,524
Polk	0.223	0.218	−2.24	36,593
Santa Rosa	0.438	0.416	−5.02	9590
Sarasota	0.558	0.52	−6.81	15,896
St. Johns	0.473	0.462	−2.32	14,119
Sumter	0.432	0.429	−0.69	2797
Volusia	0.456	0.406	−10.96	28,160

[a] See Appendix A for definitions of segregation measures.
[b] The Dissimilarity Index values for 2005 and 2013 are predicted based on the individual district values of the foreclosure variables in 2005 and 2013.

expectation, there are a number of noteworthy findings among the estimated parameters on the control variables.[44] Specifically, we find that unaffordable apartments within the white portion of school districts reduce segregation as measured by the dissimilarity and white isolation indices.[45] Within black areas, we find that an increase in the stock of affordable owner-occupied single-family units reduce segregation as measured by four of the five indices under consideration.

7. Conclusion

The foreclosure crisis had a wide range of negative impacts on families that lost their homes, financial institutions, local governments, and the owners of properties in neighborhoods beset by mortgage default. In this paper, however, we have provided evidence that there has been at least one positive outcome from the crisis: it has reduced racial segregation in public schools. Our results suggest that this reduction in segregation has largely occurred as the result of foreclosures and recent REO properties increasing the stock of rental and affordable housing in predominantly white neighborhoods.

While we see our paper as a contribution to the literature that has focused on the consequences of the foreclosure crisis, we also see it in a wider light. The crisis created a natural experiment to investigate claims that school segregation can be reduced through supply-side housing policies. Our results support these claims. In particular, our findings suggest that the dramatic rise in recent REO single-family homes offered for rent in white areas brought many black families into these neighborhoods, reducing district-wide segregation.

In light of these results, the question is: how can policy be used to increase the affordable housing stock in neighborhoods that have previously been out of the economic reach of most black households? One of the more popular approaches to addressing this policy question is the use of inclusionary zoning ordinances that require developers of housing projects to set aside a percentage of their units at below-market prices.[46] The financial feasibility of developments subject to inclusionary housing requirements and the frequent political opposition of incumbent residents to the construction of affordable housing would likely be significant impediments to the widespread adoption of inclusionary zoning policies. An alternative approach that could be used to encourage growth in the affordable housing stock in high-income neighborhoods is the use of impact fees to offset the fiscal burden associated with an increase in the number of multi-family and low-value single-family units (Burge and Ihlanfeldt, 2006).[47] Another approach would be to allow state and federal government to exorcise more control over local land use regulation, at least as it impinges on the construction of affordable housing in school attendance zones with higher performing schools. Given the national importance attached to improving the academic achievement of minority children, it may be time to make this change.

Appendix A. Index construction appendix

A.1. The dissimilarity index

Say that there are A_k members of Group A in School District k and B_k members of Group B in School District k. Now let $b_{i,k}$ denote the number of members of Group B in areal unit i within School District k and define $a_{i,k}$ similarly. The Dissimilarity Index for School District k is defined as

$$DI_k \equiv \frac{1}{2}\sum_{i=1}^{N}\left|\frac{a_{i,k}}{A_k}-\frac{b_{i,k}}{B_k}\right|$$

The possible values of DI_k range from 0 (a perfectly even distribution across areal units) to 1 (complete segregation).

A.2. The exposure (interaction) index

Let $N_{i,k}$ denote the total population of areal unit i in School District k. Say that there are A_k members of Group A in School District k and B_k members of Group B in School District k. Now let $b_{i,k}$ denote the number of members of Group B in areal unit i within School District k and define $a_{i,k}$ similarly. Then the Exposure (or Interaction) Index of Group A to Group B is defined as

$$E_{k,A,B} \equiv \sum_{i=1}^{N}\frac{a_{i,k}}{A_k}\frac{b_{i,k}}{N_{i,k}}$$

$E_{k,A,B}$ ranges from 0 to 1, where higher values are associated with more interaction between members of Group A and Group B.

A.3. The isolation index

Let $N_{i,k}$ denote the total population of areal unit i in School District k. Say that there are A_k members of Group A in School District k. Now let $a_{i,k}$ denote the number of members of Group A in areal unit i within School District k. Then the Isolation Index of Group A is defined as

$$I_{k,A} \equiv \sum_{i=1}^{N}\frac{a_{i,k}}{A_k}\frac{a_{i,k}}{N_{i,k}}$$

[44] Given the size of the control set, we do not report the estimated coefficients on all of the control variables. The full results for all of the segregation models are available upon request.

[45] The finding that it is the unaffordable and not the affordable rental units that matter likely reflects the fact that the latter units are relatively scarce within white areas.

[46] Schwartz (2010) suggests that inclusionary zoning may be more than an effective policy for desegregating public schools. She finds that children that were randomly assigned to attend low-poverty schools as a part of Montgomery County, Maryland's inclusionary zoning program achieved higher scores on standardized tests than did peers that were assigned to high-poverty schools.

[47] Burge and Ihlanfeldt (2006) provide evidence suggesting that the imposition of impact fees by suburban jurisdictions increases the quantity of multi-family housing receiving project approval. More of this otherwise undesirable type of housing gets built because the impact fee revenue helps to offset the negative externalities emitted by the housing, including the fiscal deficit that it allegedly creates.

$I_{k,A}$ has a lower bound of 0 (no isolation) and a maximum of 1 (complete isolation).

A.4. The theil information theory index

In contrast to the indices discussed above that quantify the segregation between two distinct group, Theil (1972) Information Theory Index is a measure of multigroup segregation.[48] Let R denote the set of groups under consideration, and let r index that set. Furthermore, let N_k denote the total population in School District k, and let N_{rk} denote the size of the group-r population in the district. Now define the proportion of the district's population that falls into group r as

$$\pi_{rk} = \frac{N_{rk}}{N_k}$$

Additionally, if N_{ik} denotes the total population of areal unit i which belongs to School District k, and N_{irk} denotes the size of the group-r population in i, we define the proportion of i's population belonging to group r as

$$\pi_{rik} = \frac{N_{irk}}{N_{ik}}$$

To calculate the Theil Information Theory Index for School District k, we first need to calculate the district's entropy measure, which is defined as

$$E_k = \sum_{r=1}^{R} \pi_{rk} \ln\left(\frac{1}{\pi_{rk}}\right)$$

E_k "can be seen as [a measure] of the 'diversity' of a population since...[E_k] is equal to zero if and only if all individuals are members of a single group," (Reardon and Firebaugh, 2002), p. 37 in which case $E_k = 0$.[49]

Next, we calculate entropy measures for each of the areal units located in School District k. These entropy measures are defined as

$$E_{ik} = \sum_{r=1}^{R} \pi_{rik} \ln\left(\frac{1}{\pi_{rik}}\right)$$

The Theil Information Theory Index for School District k is then defined as

$$H_k = \sum_{i=1}^{N} \left[\frac{N_{ik}(E_k - E_{ik})}{E_k N_k}\right]$$

H_k ranges from 0 (no segregation) to 1 (complete segregation).

When constructing the Information Theory Index to summarize the spatial distribution of the housing stock within a school district, i indexes SAZs and R is a set of the following types of housing units broken down by both affordability status and tenure status: single-family units, condominium units, and multi-family units.[50,51] In this application, values of H_k near 0 occur when each SAZ within the district has includes a wide variety of different housing options, while values of H_k near 1 occur when there is limited heterogeneity in the housing stock within a SAZ as compared to the heterogeneity of the housing stock between SAZs.[52]

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[48] See Reardon and Firebaugh (2002) for an extensive discussion of such measures and their properties.

[49] In the literature, it is common to define $0 \ln(0) = 0$ because $\lim_{x \to 0} x \ln(x) = 0$ (Roberto, 2015), p. 9.

[50] For example, one element of the set is affordable, owner-occupied, single-family homes.

[51] For these calculations, the single-family home counts include mobile homes.

[52] For instance, if the housing stock in some SAZs was comprised entirely of owner-occupied single-family units, while the stock in other SAZs was comprised solely of multi-family units, we would observe a high value of H_k.

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