Environmental Justice and Green Schools—Assessing Students and Communities' Access to Green Schools

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Abstract

Objective

We investigate equity in the distribution of green schools, what kind of student populations they serve, and what kinds of communities host them.

Methods

Leveraging national school enrollment data (2000–2014), Leadership in Energy and Environmental Design data, and communities' characteristics data from 2010 U.S. Census, we estimate logit models to examine the association between green schools and student and community demographics.

Results

Higher percentages of minorities in both student population and hosting neighborhood are associated with greater likelihood that new schools are green. New schools in more affluent and less educated communities are less likely to be green.

Conclusion

There is a lack of evidence for environmental injustice in students' and communities' access to new green schools in the United States. New schools serving lower-income and minority families and children are more likely to be green, although environmental justice indicators such as education show somewhat "unjust" patterns.

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School environments, as an important environmental amenity for both children and communities, can be a crucial issue in the arena of environmental justice (EJ). Although there is an emerging EJ literature focusing on environmental amenities, the majority of these studies investigates inequitable access to urban parks and green space. The systematic evaluation of inequities in children and community access to green school buildings is still rare.

Given the critical nature of schools, more attention has gone to improving schools' physical environment through healthy and green design and operations (Baker & Bernstein 2012). Among public infrastructure spending, K-12 facilities receive a large share of government infrastructure investments. A report by the Center for Green Schools of the US Green Buildings Council (USGBC) estimates that the nation has spent an average of $99 billion annually on school maintenance and operations, new school construction, and school improvement projects between 2011 and 2013 (Filardo 2016)[1]. The enormous capital investment in school environment conditions is likely to impact students and communities inequitably (Filardo 2016). Given previous evidence that minority students are more likely to attend schools near hazardous facilities (Pastor, Sadd, & Morello-Frosch 2002), and to suffer disparate health impacts and diminished school performance (Pastor, Morello-Frosch, & Sadd 2005), EJ scholarship stands to advance the understanding of the inequalities in the processes and outcomes of siting and building new green schools.

In this paper, we investigate the spatial distribution of new schools in the United States and how the demographic characteristics of those new schools' students and their host communities differ by whether the school is classified as green or not. We focus just on new

[1] It is more than a third of total local and state government's spending, details see http://www.governing.com/gov-data/state-local-government-construction-spending.html

schools built between 2000 and 2014, as students and communities receiving new schools differ from those with older, existing schools. We evaluate whether (1) race and income attributes of students or of host communities explain green school status, and (2) whether the EJ relationships differ between public and private schools. The results of our logit models offer important insight into the distributional equity of green schools across students and communities.

This paper makes several contributions. First, we contribute to the EJ discourse by further shifting attention to include environmental benefits and provide new evidence on how environmental amenities are distributed in society. Second, we contribute to methodological improvements in EJ literature, which has long been constrained to using residential proximity to a hazard as a proxy for actual exposure. After customizing the areal containment radius based on facility-specific exposure amounts, we compare the EJ results for user (student enrollment) characteristics with those socioeconomic measures commonly used for community-scale EJ research. Not only do we measure users' direct exposure to environmental goods, our analyses also compare community and enrolled children's demographics to see if measuring direct exposure provides consistent results. Third, we also overcome a common challenge of finding an appropriate comparison group in EJ studies by focusing on only newly constructed schools to assess the likelihood to receive new green schools so that EJ communities and other communities selected in this study have equal chance to receive new school buildings. Fourth, we also add new empirical evidence to the green-building literature by analyzing equity concerns related to the Leadership in Energy and Environmental Design (LEED) certification program. In particular, we examine a subset of LEED buildings and also contribute more generally to understanding inequality of school facilities – an overlooked aspect for social justice in the education system. Lastly, as a particularly vulnerable group, children present certain behaviors such as higher mouth breathing rate that often lead to a higher susceptible rate to environmental risks but they have not received significant attention in EJ studies (Gray, Shadbegian, & Wolverton 2010). Among a few EJ studies examining children, however, almost all focus on the environmental risks and hazards (e.g., Friedrich, 2000; Pastor Jr et al., 2005) instead of environmental amenities.

Green Buildings and Green Schools in Environmental Justice Research

EJ research investigates the disproportionate distribution of environmental "goods" and "bads," with a majority of empirical studies focusing on the burden of the bads falling on communities of racial and ethnic minorities, lower income, and other vulnerable groups (Agyeman 2005; Brulle & Pellow 2006). However, EJ research that investigates the other side of the story, the positive environmental conditions or environmental amenities,[2] has traditionally been overlooked. A few related articles have explored EJ aspects related to schools, such as Neal's (2008) discussion of systemic issues in EJ and school siting and Pastor, Morello-Frosch, & Sadd's (2006) examination of air toxics exposure and California schools (Neal 2008; Pastor, Morello-Frosch, &Sadd 2006). Though Pastor et al. (2006) observe significant disparities in exposure of students to different levels of ambient air quality, calls for more attention to inequities in school environmental quality continue (Mohai et al. 2011). Kweon et al.'s (2018) recent study of school locations focuses on Michigan public schools' proximity to environmental hazards like highways and industrial facilities. Though their interest is largely about proximity to and impact of these hazards, they do raise justice concerns when observing that schools closer to hazards tend to have greater shares of minority students.

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[2] The preoccupation in the EJ literature with environmental burdens in part reflects some historical context and partly reflects a particular framing (i.e., disamenities are merely the absence of amenities, local public bads the inverse of public goods). Accordingly, some empirical studies of the distribution of environmental amenities and positive externalities can be found in literatures not labeled "EJ" or directly situated within that discourse.

The notion of “green buildings” emerged in the late 20th century for structures improving the sustainable and efficient usage of energy, water, and materials of buildings and life quality of people who spend time inside the building. The literature on green buildings typically emphasizes the benefits to building owners and tenants, such as higher sales prices (Deng & Wu 2014; Eichholtz, Kok, & Quigley 2013) and rents (Chegut, Eichholtz & Kok 2014), longer rental contracts (Chegut, Eichholtz & Kok 2014), better employee performance (Singh et al. 2010), and even impacts on investors (Eichholtz, Kok, & Quigley 2013) and other stakeholders. A few studies examined the geographic context of green building adoption (Hsieh & Noonan 2017; Kok, McGraw, & Quigley 2011; Simcoe & Toffel 2014). Though not focused on “justice” or equity concerns, prior research has shown that green buildings are more prevalent in wealthier cities (Choi 2010; Cidell 2009), although that may be driven more by demand for regulation than through markets (Fuerst et al., 2016). Income and other socioeconomic factors may capture a taste for signaling green rather than better-performing buildings (Hsieh & Noonan 2017). Even evidence that LEED office buildings’ market penetration rates negatively relate to a central city’s percentage of white population (Choi 2010), however, offers little information about the equity of use and access of these buildings. Systematic evaluation of the beneficiaries and users of green buildings, as well as the potential inequalities in the access to green buildings, is still rare.

Data and Research Strategy

We focus on the LEED for Schools Rating System, a subcategory of LEED certification launched in 2007. LEED for Schools addresses unique issues related to school spaces and children’s health, such as classroom acoustics, mold prevention, environmental site assessment, and schools’ surrounding ecosystems (Adler 2009). Although LEED dominates green-building certification in the US, other certification frameworks and uncertified green buildings complicate any study of green building penetration into the built environment (Matioff, Noonan, & Flowers 2016). Thus, our analysis includes not only LEED-certified schools but also those not yet certified by LEED but started LEED process and identified by the Center for Green Schools.

Measuring Affected Communities

One crucial methodological issue identified in empirical EJ literature hinges on the spatial unit of analysis or defining the "affected communities" (Mohai and Saha 2006). This matters for our study because LEED certification may not only have an impact on students and staff but also influence developments in the community (Cohen 2010). Public schools' libraries and facilities are often used as public space for community meetings and gatherings (Aabø, Audunson, & Vårheim 2010), directly exposing neighbors to the environmental amenity. A common approach, the "unit-hazard coincidence" model (where exposure is based on whether geographic units like counties coincide with some environmental hazard) could be applied in our context, albeit with green schools as the "hazard." Mohai and Saha (2006), however, argue that the "unit-hazard coincidence" model does a poor job in identifying the location of residential populations close to hazardous sites because the hazardous sites are normally located near the border of the host unit. Our application avoids much of this concern by measuring the population directly exposed – the students enrolled in the school – rather than just a broader community proxy.

Nonetheless, we remain interested in community influencers of and recipients of green schools. The neighborhoods hosting new schools can be both drivers and beneficiaries of green-school adoption. Neighborhood characteristics like income might affect the likelihood of a new school being green through political or financial means. Neighborhood characteristics might also approximate for those most immediately "exposed" to the new school, perhaps because children in those homes might attend that school, they may be more likely to use it for community events, or their community quality is affected by it. For this reason, we mitigate the border problem in our research in two other ways. We follow the EJ literature employing buffer analysis to create buffers around schools to capture community characteristics using QGIS software. The first buffer is simply the school's host Census tract. The second buffer extends that to all adjacent tracts, the third buffer extends to all tracts adjacent to those, and so on. The relevant school-age populations are based on grade-level school enrollment data for each school (see Table 1). Whether a school has education activities in preschool, elementary school, middle school, or high school (or multiple levels) determines which age ranges from Census tabulations at the tract-level correspond to that school. Then, for each school, we calculate the relevant school-age populations in its first, second, and third buffers.

Table 1 insert here

Lastly, we compare the school-age population in schools' buffers with school enrollment to determine which buffer best represents "affected communities." We use US census data of population counts by age group to approximate school-age children.[3] Doing so lets us calculate which buffer size is sufficient to contain enough children based on school-specific enrollment. For each new school, its smallest buffer level that contains more school-age children than the school's enrollment is selected as the "neighborhood" for that school. Thus, each school has its own custom-drawn "affected community" that is drawn large enough to contain enough children to fill the school. Rather than a one-unit-fits-all approach, our definition of neighborhood captures schools' different scales, as larger schools – relative to the density of school-age

[3] We use the youngest age group (age 0-4 years) for the preschool population, the next category (age 5-9) for elementary school, the next (age 10-14) for middle school, and the next (age 15-19) for high school.

children around it – have larger "affected communities" and thus larger neighborhoods. We then use QGIS to calculate income, education, and racial demographics within the buffer.

Direct Exposure - NCES School-level data

An important contribution of this analysis is its examination of the characteristics of school children who are directly exposed to the school environment. We obtain school enrollment data from the National Center for Education Statistics (NCES), which include data for all US public schools annually and private schools biennially. We compare the 2000 and 2014 datasets to identify all new schools built between 2000 and 2014. We then use school-level data, including student enrollment information by grade, student racial composition, subsidized school lunch program participation[4], and school street address for the year 2014-2015 for public schools and the year 2013-2014 for private schools, because NCES surveys public and private schools at slightly different times.

A central challenge in empirical EJ studies is to find appropriate control groups of counterfactuals (Mohai, Pellow, and Roberts 2009; Mohai and Saha 2006; Noonan 2008; Pastor, Sadd, and Hipp 2011). Given the arbitrariness of many previous studies' control groups, such as all other tracts that do not contain a hazardous facility or any adjacent tract or county (Noonan 2008), our focus on all new schools offers a more relevant comparison group. Older schools, for instance, may be unsuitable comparisons because these schools may tend to concentrate in poorer, stagnant areas where different preexisting demographic compositions exist, and might not reflect similar siting or enrollment processes as for a new school. Limiting the comparisons to new schools gives their students and communities equal chance to receive a new school.

Analytical Approach

[4] Subsidized school lunch program participation information is not available for private schools.

Our analytical approach follows that of typical EJ analyses (i.e. Noonan, 2008) by explaining the variation in environmental quality by an array of socioeconomic indicators and control variables. This allows for a test of whether new schools being 'green' systematically varies by ethnicity and income of their students and their school neighborhoods. This EJ analysis focuses on, *given that a new school has been built*, whether it is green or not. We hypothesize the propensity to build new green schools is associated with 1) the student body's racial composition and family income levels (*H1*); 2) EJ socio-economic measurements based on community demographics (*H2*); 3) both students' and community's demographic characteristics (*H3*).

To test these hypotheses, we first run three sets of logit models controlling for some school characteristics and state effects. Model 1 explains whether new schools are green or not using the ethnic composition and family economic status of school children (corresponding to *H1*). Model 2 tests whether the schools' neighborhood characteristics are correlated with schools' green status (corresponding to *H2*). To test Hypothesis 3, we estimate a nested model (Model 3) that includes both student demographics and the neighborhood characteristics.

The results for each model also include χ^2 tests of the hypothesis that the model's EJ variables' coefficients are all jointly equal to zero. These tests examine whether the EJ variables collectively help explain the variation in green schools, even if individual EJ variables might not be a significant predictor. For the nested model, we also conduct separate χ^2 tests of whether the student-based EJ variables and whether the neighborhood-based EJ variables are jointly significant. We also explore whether the effects of EJ variables differ by schools' locations (urban vs. rural) and by ownership (public vs. private). Public and private schools' different funding resources, incentives, and constraints can affect their interest in and ability to build to green standards. Public and private schools follow different decision-making processes in selecting to build green, where to site their schools, and which students to enroll. In addition, people of color and low-income households tend to be concentrated around the urban core and low-income inner-ring suburbs (Wolch, Byrne, & Newell 2014). Urban and rural areas also often have different constraints, population growth, and development patterns, and may attract green schools with different missions. We hypothesize that ethnic income disparities for new green schools may differ based on school ownership type (*H4*) and urban-rural classification (*H5*).

To test Hypotheses 4 and 5, we estimate another set of logit models that interact EJ variables with a private school indicator variable (*private*) and an urban school indicator variable (*urban*). Analogous to the initial logit models, we first estimate a model with only student-related demographic characteristics (*Model 4*), then a second model with only neighborhood demographic characteristics (*Model 5*), and a nested model with both student- and neighborhood-based demographics, with interaction terms for all (*Model 6*).

Construction of Variables

Dependent variable

Our dependent variable (*Green*) is binary, measuring whether a new school has registered with the USGBC, including both LEED-certified schools and LEED-registered but not yet certified schools. In our dataset, 2,159 LEED-registered (including certified) schools are identified as "green schools" (6.4% of new schools in the U.S.). To identify where green schools are, we match USGBC's LEED school projects data to NCES's dataset of new schools built between 2000 and 2014 based on both school name and geospatial location using GIS tools. According to the USGBC, 48.4% of LEED-registered schools have been certified between 2000 and 2015, while an even higher proportion (58.4%) of LEED-registered schools have demonstrated improvement towards sustainability by earning points towards LEED certification.

LEED-registered schools are also on average greener than ordinary schools (*Green*=0) due to their financial commitment to LEED certification and their access to USGBC resources.[5]

Independent variables

The independent variables in the logit regressions come in three types: students' demographics, community demographics, and control variables. NCES data provide information on the percentage of African American students and Hispanic students in each school, which serve as our measures of student ethnic composition. Since a traditional EJ measurement, income does not exist in student-level data (i.e., household income is unavailable for enrolled students), we use the percentage of students eligible to participate in the free and reduced-priced lunch program under the National School Lunch Act as a proxy for income. This income proxy *lunch share* is set to 0 for all private schools because this program only exists for public schools.

For each school, its surrounding neighborhood's demographic data derive from 2010 US Census tract-level data. The percentages of African American population and of Hispanic population in the buffer surrounding each school represent neighborhood ethnic characteristics. We use the (logged) average household income variable in the buffer to capture economic status of neighborhoods. In addition, we use percentage of college degree holders, because the EJ literature has suggested that more educated population tend to be more politically active and more likely to be involved in policy making processes (Ringquist 2005, 2011). The measurement of education is only included in the neighborhood models, however, because its analog for

[5] Schools pay $1200 to register with LEED if they are USGBC members, and $1500 if non-members. Once registered with LEED, schools have access to USGBC's online Arc platform that provides solutions to achieve LEED certification, and USGBC's customer service. Each school is also assigned a dedicated LEED coach with rich experience in green building and LEED expertise to advise during the LEED certification process.

school-children either does not apply (i.e., children's college education) or is unavailable (i.e., students' parents' educational attainment).

School ownership is measured by a dummy variable (*private*), which is coded as 1 for private school, and 0 for public school. School location is measured by a dummy variable (*urban*), which is coded as 1 if the host tract of a school is in urban area per the 2010 U.S. Census, and 0 otherwise. Private schools and schools in urban areas account for 30.8% and 63.0% of all new schools, respectively. We control for (logged) total student enrollment, because larger schools may have a different capacity for going green (perhaps because the fixed costs of environmental improvement account for a smaller share of large-budget buildings) and school size correlates with demographics. Lastly, we control for the education services (i.e., grade levels) provided by schools and the state in which it is located.

Table 2 insert here

Findings and Results

Table 3 summarizes the results of our basic logit regression model (Models 1-3). Overall, they show very strong roles for income and race in explaining the likelihood of new schools being green. The basic results point to some unexpected relationships, which we unpack via interaction terms with *private* and *urban* in Table 4. To provide a better sense of the magnitude of these relationships, Table 5 displays the marginal effects for some of these coefficients.

Table 3 insert here

All three logit models in Table 3 consistently show that shares of African-American and Hispanic students in schools and in the communities are statistically significantly and positively associated with higher likelihood of new schools being green. Income measurements show mixed results. Our proxy for student income (*lunch share*) suggests that wealthier students are more likely to have their new school be green, and wealthier neighborhoods appear less likely to have their new schools be green. In general, Table 3 models show that new schools will be more likely to be green in neighborhoods with lower income and higher percentages of minorities enrolled in the school and of residents in the neighborhood. These results do not provide strong support for an "unjust" pattern of allocating green schools among new schools. The results also show, however, that a higher percentage of college-degree holders in the neighborhood is associated with greater likelihood that new schools will be green. These schools that "go green" may attract more educated neighbors, or more educated residents may effectively push for greener schools. The control variables are generally consistent across all three models, which show that bigger schools (larger enrollment) and those in urban areas are more likely to be built green. Though private schools appear more likely to be green, that result is not robust to including neighborhood characteristics. Among school types, new schools with pre-K programs are more likely to "go green" than other school types.

The nested model does raise concerns about multicollinearity among EJ variables measured at the student level and the neighborhood level. When running a collinearity analysis, the VIF scores are less than the benchmark of 10 for all the regressors (The largest VIF is 3.67, for *% Hispanic in school* in Model 3). Despite some collinearity between the student and neighborhood demographics, they both have significant influence in explaining which new schools are green buildings. In Model 3, the student-level coefficients are jointly significant ($\chi^2(3) = 9.34$, $p<0.03$) as are the neighborhood-level coefficients ($\chi^2(4) = 252.14$, $p<0.01$). The marginal effects of the coefficients in Model3 appear in Table 5. As an example, Figure 1 depicts the marginal effect of *% African Americans in school* on the likelihood of a new school being green. This visualization indicates how the likelihood rises substantially with a greater share of minority students, especially in light of the overall rarity of green schools. It also shows how new private schools have greater likelihood of being green that public schools, but not as a great a difference as for urban versus nonurban schools.

Figure 1 insert here

Table 4 shows the tests of whether the main effects of these EJ variables differ by ownership or location. Models 4-6 generally show similar results to the basic models, with the EJ variables and their interactions all jointly significant in each model. After adding interaction terms, African American and Hispanic variables remain positively related to green schools both in the student level and the neighborhood level. Model 6, which includes both student and neighborhood EJ characteristics, nests models 4 and 5 as special cases. This more flexible model shows strong positive main effects of *% Hispanic in school* and *% College degree in neighborhood*, and negative effects of *lnIncome in neighborhood*. These main effects, however, apply only for public schools (i.e., *Private* = 0) in rural areas (i.e., *Urban* = 0). Effects for other ownership or location combinations requires summing coefficients.[6] Though many of the EJ-related coefficients are individually insignificant, they are all jointly significant in each of the models in Table 4. The student-level EJ coefficients are jointly significant ($\chi^2(8) = 22.73$, $p<0.01$) as well as the neighborhood-level EJ coefficients ($\chi^2(12) = 253.95$, $p<0.01$). Table 4 does not lend itself to easy interpretation of the various EJ variables and their interaction terms' coefficients, but the other control variables are more straightforward. The positive coefficient for *Urban* in Table 3 appears to be driven by the private schools in urban areas. Other aspects of school size and type no longer remain individually significant in Model 6. Overall, the results

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[6] For example, to appreciate the effect of a higher percentage of Hispanic students in Model 6 from Table 4, the main effect (coefficient = 0.96) applies only for public schools (i.e., *Private* = 0) in rural areas (i.e., *Urban* = 0). The effect of a higher percentage of Hispanic students in private rural schools, for example, would require combining the coefficient from the *Private x Hispanic school* interaction term as well as the *Private* dummy variable.

from Model 6 suggest that some factors – neighborhood income and educational level – are generally significantly associated with new schools' green status, but other demographics' relationships with new schools' green status depends on the location or ownership of the school.

Table 4 insert here

Table 5 shows the marginal effects of the EJ variables in the previous models.[7] First, the "All" column shows the marginal effects corresponding to the results in Model 3. Increasing by 10 percentage points the share of the new school's neighborhood with a college degree is associated with an almost two percentage-point increase in the likelihood that the new school is green. Against a baseline probability of about 6.4%, a rise of two percentage point is substantial.

As these significant marginal effects are essentially averaged effects across the different sorts of new schools, Model 6 unpacks those effects for the four combinations of public/private and urban/nonurban schools. Table 5 shows the marginal effects from the EJ variables in Model 6 in four columns, each corresponding to a different sort of new school. This reveals that the neighborhood income and education marginal effects remain largely independent of ownership and location. Conversely, the positive marginal effect of neighborhood African American share is largely driven by new schools in rural areas. The positive marginal effect of *% Hispanic in school* is by far the strongest in public schools outside of urban areas. The positive effect of *% African American in school* appears to derive from public urban schools. The marginal effects in Table 5 also indicate a positive relationship between student wealth and probability of a new school being green only in urban (public) schools.

Table 5 insert here

[7] Note that student-level college is not applicable in any of the models, and school 'income' is *lunch share*, for which there is no variation in private schools.

To summarize, Table 5 shows strong but nuanced evidence of differential access to new, green schools based on ethnicity and race. Across all new school types, greater shares of minorities – in the student body and in the neighborhood – are associated with greater probabilities that new schools are green. Conditional on the other controls, wealthier neighborhoods' new schools are less likely to be green than poorer neighborhoods. Nonetheless, one of the strongest indicators – neighborhood educational attainment – consistently shows that the propensity for new schools to be green rises with education. These strong patterns may be driven by different types of schools, such as public schools or those in rural areas. The models with interaction terms suggest that rural schools drive the positive effects of minorities in the neighborhood and the public schools may drive the positive effects of minorities in the students.

Marginal effects are fairly consistent across the columns for community income, and somewhat consistent for community education levels, while they vary more noticeably for the other EJ variables. For all school types (urban/rural and public/private), a ten percent increase in college degree holders in communities is associated with an increase of 1.8 to 2.7 percentage point in the likelihood to host a green school across the school types.

Given that only about 6.4% of new schools in our dataset qualify as green, the marginal effects in Table 5 represent substantial effect sizes generally. A rural public school with 31.7% of its students Hispanic (at the 75th percentile among rural public schools in terms of *% Hispanic in school*) compared to a new school with 3.6% of its students Hispanic (25th percentile), would be 2.2 percentage points more likely to be green. A ten percent greater neighborhood income predicts an approximately 0.38 percentage point decrease in the likelihood of the new school being green. To further illustrate the magnitude of these marginal effects, as in Figure 1, compare a school with 0% black enrollment with one with 70% black enrollment (i.e., basically something at the 10th percentile with something at the 90th percentile). The 1.5 percentage point increase in the probability of the new school being green is substantial. Students in new schools more likely to have their new school be green if they more of the student body is minority.

Conclusion and Discussion

As green buildings proliferate, who has access to them – especially children from different social classes – poses an important emerging issue for environmental justice. Matching a set of green schools to a national list of new schools post-2000 allows a spatial analysis of which communities' and which students' new schools tend to be green. This paper addresses a common difficulty in EJ studies, how to measure affected communities, by adopting two complementary measurements: (1) enrolled student characteristics and (2) community characteristics. A buffer analysis identifies neighborhoods surrounding each school, customized to each school to contain just enough children enrolled in that school. Empirical models to explain which new schools are green are estimated using demographics of the schools' student enrollment and their neighborhood demographics from the 2010 census. Through these analyses, we find a general reverse injustice story with all ethnicity variables despite EJ indicators such as education show somewhat "unjust" pattern. A higher percentage of minorities in both the student population and the hosting community is associated with greater likelihood that the new school is green. More affluent communities are less likely to host a green school, although the effect of student's family income level is not significant. We also find that more educated communities are more likely to receive new green schools. From marginal effects, we find the positive effects of minorities in the community may come from rural schools in the case of blacks and from private rural schools in the case of Hispanics. The positive effects of minority student bodies may be driven by public schools. These results show that current distribution of new green schools tends to benefit lower income and minority family and children. Public policy could encourage, reinforce, or formalize a nationwide pattern that has formed seemingly without national regulation or much deliberate, systemic policy.

Despite matching comparison and treatment groups into the same period time, we are still unable to derive causality from our research. In other words, this research provides a systematic picture of what types of communities receive green schools, but we do not identify causal pathways or how policy makers might influence these outcomes. Because the nature of the cross-sectional data, our focus is not on causality or how decision-making processes determine the outcomes of locations of green schools. Rather, we focus on the outcomes of how green schools is distributed. First establishing the current patterns of distribution of green schools is vital to assessing the environmental justice associated with these green buildings and this vulnerable population. Conducting a cross-sectional spatial study like ours is a critical step in evaluating the distributional equity aspect of green policies, including relatively laissez faire policies.

This analysis treats the various decision-making processes as black boxes; thus we cannot distinguish between community demand for green and other drivers.[8] Household sorting into green schools may not be a major factor. Estimating our models with neighborhood variables data from the 2000 Census rather than the 2010 Census, for instance, does not alter the results much. If green schools 'attracted' minorities, poor, or more-educated household to the area, then we might expect the neighborhood associations with 2010 measures to differ from those with measures from 2000. Including state-specific fixed effects, however, does substantively affect some results (e.g., Hispanic student coefficient loses its significance). Also, including an indicator for the presence of a local USGBC chapter in the logit models reveals a positive and

[8] A few sensitivity analyses have been conducted to explore the causal mechanisms for green school adoption. Results not reported here but will be made available upon request.

significant role for more organized or concentrated expertise in green building. Even conditional on USGBC chapters, the main results here do not substantively change and evidence of inequitable access to green schools is limited. Still, these preliminary estimations suggest some economic and policy drivers of green school adoption. To better inform our understanding of these adoption processes, future research may combine more detailed, time-series data with case studies for more explicit tests of state and local-level policies and other causal pathways.

Another caveat of our study is that we cannot directly measure the actual geographical boundary of each school's catchment zone for our national sample of all new schools. Fortunately, we can directly include information about the ethnicity and income of the enrolled students. The location and income of the students, however, remains only approximated. And, given that our income proxy is students' enrollment in a subsidized lunch program that is only available for public schools; we cannot assess student's family income for private schools. Although our models treat "green school" as binary, and impacts of exposure to green schools, such as indoor air quality or a more productive learning environment, are not measured in the study, it is still significant improvement for EJ studies to be able to direct analyze student-level characteristics to identify who has been access to green learning environments. Future research explaining the varying greenness among both brown and green schools is warranted. Further, by including both the characteristics of the exposed "users" (students) and of the hosting neighborhoods, we can identify the equity of exposure distinct from different rates of obtaining or allowing green schools in a community, given that a new school is being built. The neighborhood EJ variables, conditional on student exposure, suggest a role for community political support in influencing the allocation of environmental quality.

Appendix

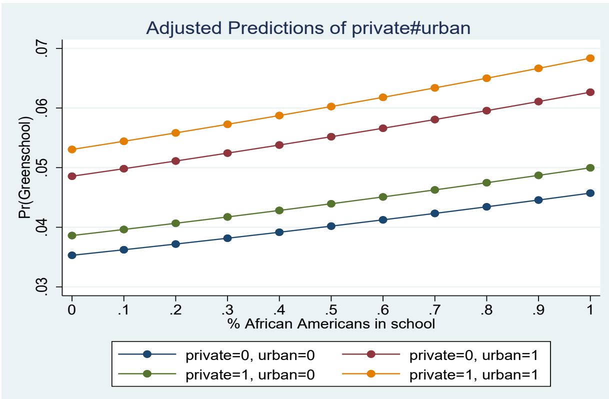

Figure 1: Illustration of Marginal Effects of African-American Student Enrollment

Table 1: Coded School Types from NCES Dataset

School type	**Education service provided**	**School type**	**Education service provided**
1	Preschool	9	elementary & high
2	elementary school	10	middle & high
3	middle school	11	preschool & elementary & middle
4	high school	12	preschool & elementary & high
5	preschool & elementary	13	preschool & middle & high
6	preschool & middle	14	elementary & middle & high
7	preschool & high	15	preschool & elementary & middle & high
8	elementary & middle	16	all students are ungraded

Table 2: Summary Statistics (N=31,507)

Variables	**Mean**	**Standard Deviation**	**Min**	**Max**
Green schools (dummy)	6.4%	.27	0	1
Private schools (dummy)	30.8%	.45	0	1
Urbanized area (dummy)	63.0%	.48	0	1
Neighborhood Demographics				
ln (Average House Income)	11.1	.43	8.82	12.82
% of Hispanics	18.2%	.22	0	.99
% of African Americans	16.7%	.24	0	.99
% with College Degree	27.3%	.17	0	1
School Children Enrollment Demographics				
Total Students' Enrollment	362.9	439.1	1	13659
% of Free Lunch Share	7.4%	.21	0	1
% of Hispanics	21.6%	.27	0	1
% of African Americans	18.9%	.28	0	1

Table 3: Basic Logit Model Results

	Model 1: School Students Demographics		Model 2: Neighborhood Demographics		Model 3: Nested School and Neighborhood Demographics	
Independent Variables	**coef.**	**std. err.**	**coef.**	**std. err.**	**coef.**	**std. err.**
% African Americans in school	.4158	(.0874) ***	-		.2698	(.1378) *
% Hispanic in school	.3937	(.1180) ***	-		.4223	(.1740) **
Lunch share in school	-.4867	(.1909) **	-		-.2760	(.1905)
% African Americans in neighborhood	-		.5940	(.1223) ***	.3570	(.1753) **
% Hispanic in neighborhood	-		.7482	(.1603) ***	.4043	(.2269) *
lnIncome in neighborhood	-		-.6835	(.1029) ***	-.6828	(.1029) ***
% College degree in neighborhood	-		3.3160	(.2166) ***	3.2449	(.2175) ***
Control						
Private	.2560	(.0729) ***	.0565	(.0720)	.0932	(.0741)
Urban	.3604	(.0559) ***	.3409	(.0567) ***	.3328	(.0567) ***
lnEnrollment	.1493	(.0233) ***	.0978	(.0236) ***	.1022	(.0237) ***
Schools with any PreK projects	.1202	(.0659) *	.1167	(.0668) *	.1149	(.0667) *
Schools with any Elementary projects	-.0846	(.0628)	-.0652	(.0638)	-.0567	(.0640)
Schools with any Middle school projects	-.0717	(.0698)	.0287	(.0720)	.0271	(.0719)
Schools with any High school projects	.0722	(.0603)	.0492	(.0617)	.0525	(.0619)
Constant	-3.1324	(.4395) ***	3.8115	(1.2012) ***	3.8462	(1.2024) ***
Pseudo R squared	0.09		0.11		0.11	
State controls	Yes		Yes		Yes	
Number of observations	31,499		31,486		31,486	
Joint test of EJ variables ($\chi 2$)	32.91 p<0.0001		275.66 p<0.0001		285.26 p<0.0001	

Notes: Models use robust standard errors. Each model is estimated with school-type dummy variables and state-specific dummy variables.
**p < .1, two-tailed tests; **p < .05, two-tailed tests; ***p < .01, two-tailed tests.*

Table 4: Logit Models with Interaction Terms

	Model 4: School Demographics with Interactions		Model 5: Neighborhood Demographics with Interactions		Model 6: Nested School and Neighborhood Demographics with Interactions	
Independent Variables	**coef.**	**std. err.**	**coef.**	**std. err.**	**coef.**	**std. err.**
% African Americans in school	0.7321	(0.1797) ***	-		0.0887	(0.3261)
% Hispanic in school	0.7552	(0.1946) ***	-		0.9645	(0.3566) ***

Lunch share in school	-0.0893	(0.2655)	-		0.2217	(0.2650)
% African Americans in neighborhood	-		0.7304	(0.2507) ***	0.6870	(0.4097) *
% Hispanic in neighborhood	-		0.9534	(0.2375) ***	-0.0909	(0.4363)
lnIncome in neighborhood	-		-0.8818	(0.2145) ***	-0.8956	(0.2121) ***
% College degree in neighborhood	-		3.3540	(0.4748) ***	3.3216	(0.4740) ***
Interaction terms with ownership						
Private×African American school	-0.2729	(0.1766)	-	-	-0.2906	(0.2787)
Private×Hispanic school	-0.3669	(0.2419)	-	-	-0.4843	(0.3658)
Private×African American neighborhood	-		0.1625	(0.2396)	0.4389	(0.3526)
Private×Hispanic neighborhood	-		-0.0070	(0.2910)	0.3729	(0.4398)
Private×Income	-		0.0500	(0.1998)	0.0077	(0.1997)
Private×College	-		0.4945	(0.4376)	0.6583	(0.4398)
Interaction terms with urban						
Urban×African American school	-0.2706	(0.1939)	-		0.4129	(0.3362)
Urban×Hispanic school	-0.3182	(0.2149)	-		-0.4638	(0.3867)
Urban×Lunch	-0.5933	(0.2861) **	-		-0.7385	(0.2876) **
Urban×African American neighborhood	-		-0.2403	(0.2637)	-0.6582	(0.4201)
Urban×Hispanic neighborhood	-		-0.3243	(0.2568)	0.3922	(0.4723)
Urban×Income	-		0.2578	(0.2257)	0.3080	(0.2246)
Urban×College	-		-0.3870	(0.4889)	-0.5375	(0.4895)
Control						
Private	-0.2760	(0.2568)	-1.0284	(2.1473)	-0.5262	(2.1451)
Urban	0.1199	(0.2723)	-2.8409	(2.3900)	-3.3318	(2.3784)
Private×Urban	0.3854	(0.1407) ***	0.4498	(0.1490) ***	0.3934	(0.1538) **
Enrollment	0.0856	(0.0385) **	0.0436	(0.0421)	0.0464	(0.0421)
Private×Enrollment	0.0733	(0.0490)	-0.0021	(0.0494)	0.0013	(0.0494)
Urban×Enrollment	0.0484	(0.0448)	0.0734	(0.0477)	0.0719	(0.0477)
Schools with any PreK projects	0.0947	(0.0674)	0.1065	(0.0684)	0.1054	(0.0683)
Schools with any Elementary projects	-0.0757	(0.0631)	-0.0545	(0.0638)	-0.0460	(0.0641)
Schools with any Middle school projects	-0.0808	(0.0699)	0.0387	(0.0736)	0.0360	(0.0735)
Schools with any High school projects	0.0528	(0.0612)	0.0477	(0.0627)	0.0527	(0.0628)
Constant	-2.8316	(0.4766) ***	6.3058	(2.3227) ***	6.4776	(2.2980) ***
Pseudo R squared	0.10		0.11		0.12	

State controls	Yes		Yes		Yes	
Number of observations	31,499		31,486		31,486	
χ^2 joint tests						
All interaction terms and EJ variables (χ^2)	49.22 p<0.0001	df=8	280.88 p<0.0001	df=12	304.39 p<0.0001	df=20

Notes: Models use robust standard errors. Each model is estimated with school-type dummy variables and state-specific dummy variables.
**p < .1, two-tailed tests; **p < .05, two-tailed tests; ***p < .01, two-tailed tests.*

Table 5: Marginal Effects of EJ variables for different types of schools

		All	**Private Urban**	**Private Rural**	**Public Urban**	**Public Rural**
% African Americans	school	0.015*	0.011	-0.003	0.028**	0.003
	neighborhood	0.020**	0.027	0.057*	-0.002	0.049*
% Hispanic	school	0.024**	0.015	-0.016	0.020	0.078***
	neighborhood	0.023*	0.025	0.058*	0.024	-0.028
Income	school	-0.015	-	-	-0.028**	0.010
	neighborhood	-0.038***	-0.038***	-0.039***	-0.037***	-0.037***
College	school	-	-	-	-	-
	neighborhood	0.181***	0.207***	0.184***	0.155***	0.178***

Notes: the 'All' column estimates are derived from Model 3, without interaction terms. The last four column estimates are derived from Model 6 with additional interaction terms.
**p < .1, two-tailed tests; **p < .05, two-tailed tests; ***p < .01, two-tailed tests.*

References

Aabø, S. et al. (no date) 'How do public libraries function as meeting places?', Elsevier.

Adler, Tina. 2009. "Learning Curve: Putting Healthy School Principles into Practice." *Environmental health perspectives* 117(10): A448-53.

Agyeman, Julian. 2005. Sustainable Communities and the Challenge of Environmental Justice. New York University Press.

Baker, Lindsay, and Harvey Bernstein. 2012. "The Impact of School Buildings on Student Health and Performance: A Call for Research I."

Brulle, Robert J., and David N. Pellow. 2006. "ENVIRONMENTAL JUSTICE: Human Health and Environmental Inequalities." *Annual Review of Public Health* 27(1): 103–24.

Cohen, Alison. 2010. "Achieving Healthy School Siting and Planning Policies: Understanding Shared Concerns of Environmental Planners, Public Health Professionals, and Educators." *New Solutions: A Journal of Environmental and Occupational Health Policy* 20(1): 49–72.

Choi, Eugene. 2010. "Green on Buildings: The Effects of Municipal Policy on Green Building Designations in America's Central Cities." *Journal of Sustainable Real Estate* 2(1).

Chegut, Andrea, Piet Eichholtz, and Nils Kok. 2014. "Supply, Demand and the Value of Green Buildings." *Urban Studies* 51(1): 22–43.

Cidell, Julie. 2009. "Building Green: The Emerging Geography of LEED-Certified Buildings and Professionals." *The Professional Geographer* 61(2): 200–215.

Deng, Yh & Jing Wu. 2014. "Economic Returns to Residential Green Building Investment: The Developers' Perspective." *Regional Science and Urban Economics* 47: 35–44.

Eichholtz, Piet, Nils Kok, and John M Quigley. 2010. "Doing Well by Doing Good? Green Office Buildings." *American Economic Review* 100(5): 2492–2509.

Filardo, M. 2016. *State of Our Schools*. Washington, D.C.

Filardo, MW et al. 2006. "Growth and Disparity: A Decade of US Public School Construction."

Friedrich, M.J. 2000. "Poor Children Subject to Environmental Injustice." *Journal of the American Medical Association* 23(3057).

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

Gray, Wayne B, Ronald J Shadbegian, and Ann Wolverton. 2010. *Working Paper Series Environmental Justice: Do Poor and Minority Populations Face More Hazards?*

Hsieh, Lin-Han Chiang, and Douglas Noonan. 2017. "Strategic Behavior in Certifying Green Buildings: An Inquiry of the Non-Building Performance Value." *Environmental Management* 60(2): 231–42.

Kok, Nils, Marquise McGraw, and John M Quigley. 2011. "The Diffusion of Energy Efficiency in Building." *American Economic Review* 101(3): 77–82.

Kweon, Byoung-Suk, Paul Mohai, Sangyun Lee, and Amy M Sametshaw. 2018. "Proximity of Public Schools to Major Highways and Industrial Facilities, and Students' School Performance and Health Hazards." *Environment and Planning B: Urban Analytics and City Science* 45(2): 312–29.

Matisoff, Daniel C., Douglas S. Noonan, and Mallory E. Flowers. 2016. "Policy Monitor—Green Buildings: Economics and Policies." *Review of Environmental Economics and Policy* 10(2): 329–46.

Mohai, Paul, and Robin Saha. 2006. "Reassessing Racial and Socioeconomic Disparities in Environmental Justice Research." *Demography* 43(2): 383–99.

Neal, Daria E. 2008. "Healthy Schools: A Major Front in the Fight for Environmental Justice." *Environmental Law* 38: 473–93.

Noonan, Douglas S. 2008. "Evidence of Environmental Justice: A Critical Perspective on the Practice of EJ Research and Lessons for Policy Design *." *Social Science Quarterly* 89(5): 1153–74.

Pastor, Jr., Manuel, James L. Sadd, and Rachel Morello-Frosch. 2002. "Who's Minding the Kids? Pollucion, Public Schools, and Environmental Justice in Los Angeles." *Social Science Quarterly* 83(1): 263–80.

Pastor, Manuel, Rachel Morello-Frosch, and James L. Sadd. 2005. "The Air Is Always Cleaner on the Other Side: Race, Space, and Ambient Air Toxics Exposures in California." *Journal of Urban Affairs* 27(2): 127–48.

Ringquist, Evan J. 2005. "Assessing Evidence of Environmental Inequities: A Meta-Analysis." *Journal of Policy Analysis and Management* 24(2): 223–47.

Ringquist, Evan J. 2011. "Trading Equity for Efficiency in Environmental Protection? Environmental Justice Effects from the SO2 Allowance Trading Program*." *Social Science Quarterly* 92(2): 297–323.

Simcoe, Timothy, and Michael W. Toffel. 2014. "Government Green Procurement Spillovers: Evidence from Municipal Building Policies in California." *Journal of Environmental Economics and Management* 68(3): 411–34.

USGBC. 2009. *LEED 2009 for Schools: New Construction and Major Renovations.*

Wolch, Jennifer R, Jason Byrne, and Joshua P Newell. 2014. "Urban Green Space, Public Health, and Environmental Justice: The Challenge of Making Cities 'Just Green Enough.'" *Landscape and Urban Planning* 125: 234–44.