Social Capital and Environmental Justice: An Agent-Based Model

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Abstract

Among several competing explanations for observed environmental injustices in society, this paper focuses on the hypothesis regarding communities' potentials to engage in collective actions against the siting of unwanted facilities. By assuming that residents have a propensity to mount political opposition to the siting of an environmental disamenity, we build an agent-based model using assumptions of the Coase theorem. The propensity is determined by the level of social capital that exists within a social network, represented as a function of 1) network size, 2) network wealth, 3) proportion of majority residents in the network, and 4) a combination of these three factors. Per the Coase theorem, the disamenity-producing firm seeks to avoid strong networks. The simulation outcomes under the four decision scenarios were unexpected: No matter how disamenities assessed the strength of local networks, avoiding strong networks did not lead to environmental injustice. This suggests that the extension of the Coase theorem by Hamilton (1993, 1995), which has been applied broadly for disamenity location choice in the EJ literature, may be an insufficient condition to alone explain the environmental justice problem. To explore what other factors may be important, to the model we added resident educational levels and the assumption that amenity-producing firms value educated residents in their location decisions. When these two factors were added and all else remained the same, the model again simulated environmentally unjust outcomes based on minority status.

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INTRODUCTION

The study of environmental justice (EJ) has accumulated often-mixed, but overall persuasive, empirical findings: communities that are mostly white and/or wealthy tend to have better environments than those that are poor and/or minority. Scholars have developed plausible theoretical explanations for this outcome. These explanations are not limited to the environmental racism argument (Bullard, 1996), but also include economic forces, technocratic criteria, partisan discrimination, political intervention, and civil society arguments (Aldrich, 2008). The thesis we examine in this paper is along similar lines to suggestions offered by Aldrich (2008), Pastor, Sadd and Hipp (2001) and Hamilton (1995). We analyze whether the firm's consideration of a neighborhood's potential for political opposition—its potential for more collective action against an undesired firm siting there—can help explain societal environmental injustice outcomes.

The noxious facility location-decision literature has been informed by the Coase theorem (1960), which predicts that a facility will locate where it does the least (monetary) harm because of the compensation cost associated with the siting (Hamilton, 1993). A firm generating externalities "cares about the *expressed* opposition in the community, which may raise the transaction costs of litigation and regulatory hearings, increase the compensation paid to the community, and increase the facility's operating costs once it is started up" (Hamilton, 1993, 102; c.f. Congleton, 1996, 190; italics in original). In calculating the compensation costs, therefore, the firm may take into account various characteristics of neighborhoods such as the number of people affected, incomes, property values, and residents' willingness to pay for environmental amenities (Hamilton, 1995). In other words, firms will consider various factors that are all highly correlated with high levels of social capital.

People who live spatially proximately share mutual interests in the safety, security, and quality of their neighborhoods, and this can lead to social networks and social capital. High levels of social capital in communities have been found to increase property values (Woolcock, 1998), decrease crime (Buonanno, Montolio, and Vanin, 2009), and make neighborhoods healthier (Steptoe and Feldman, 2001). Crucially, social capital may also play a role in the propensity of a community to organize against environmental hazards, and the more social capital a community possesses, the more likely they are to avoid having environmental hazards sited in their community (Aldrich, 2008).

Were social capital distributed proportionately across the socioeconomic spectrum, then there would be no reason to expect it to have a relationship with environmental justice. However, social capital builds in those communities that have the strongest ties (Coleman, 1988), and communities with stronger social ties tend to be made up of a large proportion of homeowners (as opposed to renters) who remain in the community for a long period of time, in close proximity to their neighbors—these communities will tend to have higher-than-average income levels—and also among the well-educated (Glaeser, Laibson, and Sacerdote, 2002). Social capital formation is also facilitated as members of a social group have more leisure time (Lindstrom, Hanson, and Ostergren, 2001), and perceive themselves as successfully accomplishing goals (Rich, et al., 1995). All these variables tend to be highly correlated with socioeconomic status, and social capital formation tends to be strongest in wealthy, predominantly white communities (Dear, 1992).

In the paper presented here, we use Agent-Based Modeling (ABM), a computational modeling technique allowing synthetic experimentation and the observation of emergent outcomes, to analyze the effects of social capital, as measured through network strength, on neighborhood ability to fend off undesired, polluting facilities. We explore whether social capital effects may help explain empirically observed EJ effects.

BACKGROUND

Collective Action, Group Behavior, and Information

It is harder for policymakers to factor unheard information, including points of view, into their decisions. Recognizing this, since attention first became focused on the problem of environmental disparities, a key solution has been to increase access to policymakers through open comment periods, public scoping requirements, and other inducements to include the public in decision-making. The Resource Conservation and Recovery Act of 1976 (RCRA) specifically requires that states, as part of their hazardous waste policies, include public participation during the entirety of the process through which a facility is planned, a site is selected, and a plan is approved.[1] Although the intent of the policy was to ensure that all affected stakeholder groups were active participants in the decision-making process, public inclusion policies tended to ignore the propensities of different populations to act collectively (Matheny and Williams, 1985).

Yet, we know that group characteristics affect a group's ability to be heard. Even in some of the earliest work on group theory, the following points are made:

[1] 42 U.S.C. §6901 – See: http://www.epa.gov/lawsregs/laws/rcra.html

> The extent to which a group achieves effective access to the institutions of government is the resultant of a complex of interdependent factors …: (1) factors relating to a group's strategic position in the society; (2) factors associated with the internal characteristics of the group; and (3) factors peculiar to the governmental institutions themselves. In the first category are: the group's status or prestige in the society, affecting the ease with which it commands deference from those outside its bounds; …[and] the extent to which government officials are formally or informally "members" of the group... The second category includes: …the degree of cohesion it can achieve … and the group's resources in numbers and money (Truman 1955, pp. 506-507).

It seems clear that in many cases racial and ethnic minorities have lower status or prestige in the society, resulting in less-forceful strategic positions. In addition, in many instances the majority of government officials are not members of the minority group. It seems reasonable that these realities make the effects of cohesion and resources all the more important in minority communities.

Since the passage of participation requirements, it has become relatively well accepted that the absence of collective action increases the probability that a community will be the site of an environmental hazard (Hamilton, 1995) and, conversely, that well-organized communities will be able to fend off attempts to site undesired facilities in their locations. It is easy to find evidence of the effectiveness of these so-called NIMBY (Not In My Back Yard) efforts in thwarting the placement of environmental hazards (Dear, 1992; McAvoy, 1998; Fischer, 1993), and thus bringing about more preferable outcomes for the residents that do organize against a proposed undesirable land use—environmentally hazardous or otherwise (Kraft and Clary, 1991; Wolsink, 1994). Historically, collective action has been more likely in wealthier, whiter communities

(Dear, 1992), while action is less likely in poor and minority communities. As a result, we are more likely to see environmental hazards in these latter neighborhoods as both private firms and governments seek to avoid political controversy, as well as the transaction costs associated with related political maneuverings (Hamilton, 1995).

Organized communities are better able to achieve more desirable outcomes, or, from another perspective, have enough political capital to force undesirable outcomes onto disorganized communities. Furthermore, as communities successfully thwart undesirable land uses, they become more emboldened by victory and organize for other purposes, perhaps to encourage desirable land uses (Rich et al., 1995). These types of outcomes can lead to virtuous cycles: Trust builds amongst individuals in the collective as the organized communities' efforts are rewarded, social capital is created and increased (Coleman 1988), more and more desirable outcomes follow, until eventually the community may become part of the local governing regime (Stone, 1989).

In contrast, when residents are unorganized and haphazardly oppose undesirable land uses, siting disamenities in their community becomes far easier for decision-makers. Subsequently, failure to thwart these sitings instills a sense of frustration, reducing the likelihood that future collective efforts will be successful, or that the community will organize at all. Over time, this frustration results in a probability that whenever an undesirable land use is necessary, the unorganized community will be an attractive site (Rich et al., 1995). Further, this effect may be enhanced by "agglomeration economies" leading firms of certain types to find benefits of clustering together (Bowen, Atlas and Lee 2009).

Expressed more generally, over time, collective action is rewarded with favorable outcomes that encourage future organization and aggregation of social capital in successful communities. Lack of cohesive collective action likely leads to less-favorable outcomes, discouraging future collective action and preventing the formation of social capital. Collective action informs the decisions made by policymakers, whether directly, in the case of public input having a specific effect on the decisions by policymakers, or indirectly when political decision makers seek to avoid political opposition and controversy. In either case, policymakers receive information from organized interests, whether in the form of direct pleas for preferred outcomes or through perceived constraints on considered options, as policymakers seek to avoid creating a need for action by an interest whose preferences and proclivities toward collective action are known (or at least strongly suspected) in advance.

Of course, information from an organized interest is one source, but not the only source, of information that policymakers consider. Organized group information may vary by importance with other factors but, at the very least, the political action (or expectation of political action) by a concerned and cohesive community almost certainly places boundaries around the options that policymakers perceive are available to them. In general, information is much more likely to be received if it comes from organized groups with high levels of social capital (Ostrom, 1994).

Hamilton (1995) in particular argues that it is rational to locate environmental disamenities where residents put up less resistance and, therefore, what appears to be race-based environmental injustice can instead be a type of placement rationality that is simply correlated with race because of minority groups' lesser levels of NIMBY action.

Social Capital and Collective Action

"Social capital is the arrangement of human resources to improve flows of future income…[it] is created by individuals spending time and energy working with other individuals to find better ways of making possible the 'achievement of certain ends that in its absence would not be possible' (Coleman, 1966: S98)." (Ostrom, 1994: 527-528). Unlike assessments of other forms of capital (say physical), measuring and understanding social capital is complicated due to its intangibility. While physical capital exists in space, social capital exists in the relations between people, and the more social capital that exists within some social structure, the more that group is able to accomplish relative to groups with less social capital (Coleman, 1988).

The foundations of social capital are obligations, expectations and trustworthiness within social groups (Coleman, 1988). These are built through actions and interactions between individuals in social groups (Ullmann-Margalit, 1977). Social capital formation is triggered in certain types of social structures, like closed systems, organizations formed for mutual interests, or amongst spatially proximate groups that share an interest in some "common" (Ostrom, 1994). It is with this last type of structure we are most interested here. Yet, we also recognize that social groupings, such as those based on income levels or racial groupings, matter to social capital formation.

As mentioned above, spatial proximity creates shared interest in the shared geography. In addition, spatial proximity can increase the likelihood that social ties, the precursors of cohesive social capital, will form.

Social Capital in the Environmental Justice Literature

In aggregate, the EJ literature finds that communities that are disproportionately White-non-Hispanic tend to have fewer environmental burdens than disproportionately minority communities. Some scholars have argued that this is a simple outcome of market and Coaseian dynamics, such that polluting firms locate both where land is cheap and where there is the least anticipated monetary compensation demand. One of Hamilton's (1995) insights on this is that the compensation demand involves transaction costs. Due to the transaction costs, compensation demands "are typically voiced through the political process" (p.110) rather than through individual negotiation with an environmentally harmful facility. However, communities in the political process are not identical, in terms of their stock of social capital and ability to overcome free-rider problems to engage in collective action. If minority communities are weak in terms of social capital, facilities may choose to locate in minority communities (Hamilton, 1995). Aldrich's (2008) recent explanation of controversial facilities based on civil society characteristics is an extension of Hamilton's insight.

The thesis is insightful and interesting as a potential hypothesis to explain the siting of environmental disamenities. The challenge is how to capture the (expressed) potential to engage in political action against the siting of unwanted facilities by communities. Two distinct approaches to examining the hypothesis are found in the EJ literature. First, Hamilton (1993, 1995) used a measure of voter turnout: the percentage of voting-age population that voted in the 1980 presidential election. In his model, the variable represents the expressed opposition to the siting of environmental disamenities and is expected to be highly correlated with the potential for collective action. Second, Aldrich's (2008) civil society assumption is that social capital is not evenly distributed within nations and the strength of civil society matters in the siting of controversial facilities. He used the percent of population change as a proxy for civil society *quality* (i.e., community solidarity) and change in percentage of primary sector employment as a proxy for civil society *capacity* (i.e., over-time changes in relative strength). Aldrich (2008) found that communities with strong membership in civil society groups had a lower chance of being selected as hosts for disamenity sites such as nuclear power plants in Japan.

Use of Agent-Based Modeling in EJ

Agent-based modeling is particularly useful for modeling the complexity of interactive decision-making by heterogeneous actors (such as residents, resident groups, and firms) in a dynamic setting (such as a city), and what emergent outcomes arise therefrom. Regardless of the research contexts within which ABM has been used, a fundamental question that ABM addresses is "Does the hypothesized microspecification suffice to generate the observed phenomenon?" (Epstein, 2006, p.15). Here, the key microspecification is the hypothesized Coaseian decision-making process. ABM helps us examine such explanations within a complex and dynamic urban system, allowing for the emergence of macro-patterns that may not be obvious outcomes of micro-behavior, and testing hypotheses about which micro-behaviors lead to observed, real-world macro-patterns.

In our own previous work, we have used an Agent-Based Model to investigate the EJ argument that environmentally unjust outcomes are caused by explicit racial discrimination in the siting of disamenities (Eckerd, Campbell, and Kim 2012), the economic-based residential-sorting argument around income levels (Kim, Campbell, and

Eckerd, 2013), and a land-use structure hypothesis (i.e., zoning) (Campbell, Kim, and Eckerd, forthcoming). Here we continue this stream of work by focusing on and incorporating the collective action argument into our ABM. In this paper, we focus on analyzing the explanatory power of an important micro-level rule that has been discussed in EJ-related research: social capital.

MODELING SOCIAL CAPITAL FOR EJ ABM

The Artificial City[2]

A complex dynamic urban system is represented by a space formed by 101x101 (10,201) plots. Each plot has (x, y) coordinates. Blocks, as proxies for neighborhoods or US Census blocks, are created by 10 x 10 set of plots, and transportation routes run between the blocks. Therefore, each block includes 100 plots and 100 blocks exist in the artificial urban environment. Each plot has two key variables—environmental quality and price. A third variable is the plot's distance to firms. Initially, a hypothetical value of 50 is assigned for environmental quality of all plots. The price of each plot, however, is assigned a value randomly drawn from a normal distribution mirroring median home prices in the United States—a distribution with a mean of $173,000 and standard deviation of $34,000 (US Census, 2010).

The simulation is also initialized with a certain number of residents (e.g., 200). Assuming a growing city such as one in the Sunbelt, a net population growth rate is set at 5%. Thus, the number of residents in the artificial city is increasing over time at that rate. We set the residents-per-firm ratio at 50:1, indicating 50 employees per firm. This means that when the simulation starts with 200 residents, 4 firms will be initialized at the

[2] The description of the EJ ABM in this paper is an overview. More-detailed descriptions are available in the other authors' works already cited above.

beginning. When there is unmet demand for jobs due to population growth, new firms are introduced to the artificial city. At each step, all plots record the distance to the nearest firm and calculate a utility score of the plots (described in more detail in the Residential Choice Processes section). Once a resident or firm takes up one plot, the plot is not available for new residents or firms.

Resident Agents

Resident agents have two attributes—race and income. The simulation begins with more majority than minority residents: 70% to 30%. Within these subgroups, the resident agents are also assigned differential incomes. Using overall US income levels (US Census, 2010) as a representation of incomes in an "average US city," majority residents are assigned an income from a distribution with mean $54,000 and standard deviation $41,000 (based on the distribution for White-non-Hispanics). Minority residents are assigned an income from a distribution with mean $32,000 and standard deviation $40,000 (based on the distribution for African Americans).[3]

Residential Choice Processes

When residents are introduced to the world, their location choices are constrained by their incomes and "similarity preferences"—preferences for living near other residents like themselves as defined by race (Schelling 1978). Because the least expensive house or neighborhood may be undesirable, no resident considers a plot that is less than twice its income level. Using the income constraint, residents also exclude any plot with a price greater than three times their income levels. Regarding the similarity-preference constraint, we set an 80% similarity preference constraint for majorities, but a 50% similarity preference for minorities. This is based on empirical findings on White and

[3] Both distributions are constrained to be no less than zero.

other races' residential similarity preferences (Clark 1992; Emerson, Yancey and Chai 2001).[4]

These income and similarity constraints limit residential choice sets; after a constrained set of plots has been identified, residents pick a plot that maximizes their utility (i.e., a plot with the highest utility score given price, quality, and distance to a job) within their choice set (cf. Courant and Yinger 1977; Brown and Robinson 2005; Pratt 1964; Rand, Zellner, Page et al. 2002). In other words, within the confines of the income and similarity constraints, residents make a siting decision based on a utility score of candidate plots. Utility scores are calculated based on the following decision criteria: pay a low price for the plot, live on a high-quality plot, and live near their jobs, as described in Equation 1.

$$u_{j,t} = p_{j,t}^{-\alpha} \cdot q_{j,t}^{\beta} \cdot d_{jk,t}^{-\gamma} \qquad \text{Eqtn 1}$$

where utility of a plot *j* at time *t* is a function of price and quality of *j* and distance between plot *j* and the nearest job, *k*, at time *t*.

An equal weight of 0.5 is set for the three decision variables (i.e., α, β, and γ are set to 0.5), indicating a balance of importance among these three factors.

Affects on Plot Price

The residential agent's choice of a plot is influenced by the price, as shown, but each agent's plot choice also influences the price of plots thereafter. Once the simulation starts, three sequential procedures are performed to decide the price of plots at each time step. First, the price at time *t-1* is negatively adjusted by an inverse distance to the nearest high-polluting firm (a disamenity) and then positively adjusted by an inverse distance to

[4] It is interesting to consider that, since the world is distributed with 70% majorities, an 80% majority similarity preference is only slightly above the base representation in the model.

the nearest amenity (a low-polluting firm). After that, prices are altered based on the income level of the residents that settle nearby (surrounding eight neighboring plots): i.e., if the income level of nearby residents is high, the plot price increases (or decreases if nearby residents are poor) by a multiplier calculated by comparing the difference between twice the average income of nearby residents and the current plot price. After this adjustment, each plot diffuses its price value to the eight immediate-neighbor plots based on a diffusion rate. Here the diffusion rate is set to 0.7, so each plot gets 1/8 of 70% of the price value from each neighboring plot added to its own at each simulation step.

Forming Social Capital

Once residents settle in a plot, residents start to form a network with other residents. We start from Coleman's (1988) view of the accumulation of social capital, arguing that social capital may be conceived of as a community "good" that can be expended. However, if higher-status communities use social capital in NIMBY-like campaigns, this has impacts beyond to communities that do not have sufficient stocks of social capital. We also gain insight from an ABM analysis by Abdollahian, Yang, and Nelson (forthcoming), which looks at social networks and their effects on the siting of high-tension power lines, but which does not examine EJ outcomes.

In building social networks we assume that the probability of being linked to a resident with the same race is higher than the probability of being linked to a resident with the different race (Vedantam, 2013). Once the simulation starts, residents who settled in a plot start to link with other residents within a certain radius (e.g. 20). The probabilities to be linked to residents of the same race or the different race can be set prior to the simulation. We are not aware of empirical studies that can inform this probability, so for this first experiment we set the probability for residents to be linked with the same race at 0.6 and the probability to be linked with the different race at 0.2. Once the link is built between residents, the link lasts for the life span.

Blocks

Blocks contain network information. At each step, blocks update the information about their residents' social networks and wealth levels. The information includes 1) the average wealth of residents within each network, 2) the number of residents within each network, 3) the proportion of majorities within the network, and 4) a combination of the three as a multiplicative term. When a new firm is introduced to the artificial city, it uses the information in its siting decision.

Firm Agents

When a firm is introduced to the simulation world, its level of pollution is randomly assigned as an integer between zero and nine. In this model, those firms that produce substantial pollution (greater than 5 on this scale) are defined as disamenities (such as Toxics Release Inventory Facilities, aka TRIFs; Transport, Storage and Disposal Facilities, aka TSDFs; etc.), and those with lower levels of pollution are defined as amenities (such as schools, museums, etc.). Low-pollution, job-creating agents are considered amenities because people and cities value jobs. The goal of firms is to find a plot based on their decision criteria.

Siting Decision Criteria

The siting decisions for amenities follow standard rationality assumptions. When there is labor demand for a new firm, new firm is created and receives a set of random patches from which it may select a location. Amenity firms select the lowest-priced plot of those within their choice sets. In previous studies mentioned above, we have varied the choices that disamenities use to select locations, but have not previously assessed results when disamenities choose locations according to the Coase theorem (as outlined in Hamilton, 1995). According to the theorem, disamenities aim to select a location that probabilistically minimizes transaction costs by focusing on those areas that appear to have the weakest social networks, and thus are the least likely to mount NIMBY opposition to the siting.

In the model, therefore, disamenities can access information about the block-by-block network characteristics mentioned above, and then make location decisions based on selecting the plot with a) the network with the fewest members, b) the network with the lowest average wealth level, c) the network with the smallest proportion of majority residents, or d) a combined measure incorporating all three of these characteristics. The combined measure is a multiplicative index of the percentile rank of the focal network on the three characteristics.[5] When selecting based on this measure, a disamenity can choose a plot with a network that has a low percentile rank in terms of size, wealth, and proportion majority.

Plot Quality When a New Firm Sites

Initially, the hypothetical environmental quality value of plots is set to 50. Once a firm's siting decision is made, disamenities degrade the quality of a plot, while amenities improve the quality of a plot. We model these environmental effects in two ways: 1) as a reflection of the pollution variable associated with the focal firm, and 2) as a function of spatial proximity. If a new disamenity is introduced to a plot at time *t* during the

[5] We use percentile rank to avoid the magnitude problems of comparing incomes measured in $1000s, numbers of residents in a network, and what percent of the network is majority.

simulation, the quality value of the plot upon which the disamenity is located decreases at *t + 1* reflecting the disamenity's pollution level (by between 6% and 9). The higher the pollution level, the larger the reduction. The quality of all plots within the block where the disamenity locates also decreases at *t + 1*, again depending upon the disamenity's pollution level (by between 3% and 5%).

Conversely, if an amenity is introduced to a plot, the quality increases based on the amenity's pollution level (by between none and 5%). The quality of neighbor plots within the block also increases via the same mechanism as the decrease associated with disamenities (but here increases are between 3% and 5%). These quality operations that are related to the pollution level of the focal firm occur at only one time period, the first time period after each new firm is introduced to the world.

Ongoing Changes to Plot Quality

During the simulation, there are two other procedures that influence the quality of plots on an ongoing basis. Similar to the changes in plot *price* described above, the *quality* of each plot at *t* is updated at every simulation step by being negatively adjusted by an inverse distance to the nearest disamenity at *t-1* and then postively adjusted by an inverse distance to the nearest amenity. After the adjustment, quality changes spread out, with decreased force based on distance, to adjacent plots (Parker and Meretsky 2004). Each plot diffuses its quality value to the neighboring 8 plots based on a diffusion rate. Here the diffusion rate is set to 0.7, so each plot gets 1/8 of 70% of the quality value from each neighboring plot.

Table 1 presents the base model parameterizations and justifications for the chosen values.

Table 1: Base Model

Parameters	Value	Reference
Random seed	Varies	Authors' assumption
The simulation world size	10,201 plots	Authors' assumption
Growth rate	5%	Authors' assumption
Initial quality of plots	50	Hypothetical value
Initial price of plots: mean, standard deviation (a normal distribution)	$173,000, $34,000	US median housing price (Census 2010)
Resident jobs per firm	50:1	Authors' assumption
Initial number of residents	200	Authors' assumption
Initial Majority | Minority composition	70% | 30%	Authors' assumption
Majority income: mean, standard deviation (a normal distribution)	$54,000, $41,000	US Income, White non-Hispanics (Census 2010)
Minority income: mean, standard deviation (a normal distribution)	$32,000, $40,000	US Income, African-American (Census 2010)
Initial number of firms	~ 4	A function of Initial number of residents and jobs per firm
Pollution level: Minimum, Maximum (a uniform distribution)	0, 10	Hypothetical value
Pollution diffusion rate	0.7	Veldkamp and Verburg (2004); Brown et al. (2005)
Price and quality exponential decay rate (δ)	1.5	Veldkamp and Verburg (2004)
Utility balancing parameters (α, β, γ)	0.5	Brown and Robinson (2006); Torrens and Nara (2007)
Resident similarity preference	80% (Majorities), 50% (Minorities)	Clark (1992)
Network Link-distance	20 radius	Authors' assumption
Network Link-life	10 steps	Authors' assumption
Probability to be linked with same race	0.6	Authors' assumption
Probability to be linked with different race	0.6 or 0.2	Authors' assumption

Experimental Scenarios

The focus of the current experiment is to examine how environmental injustice outcomes vary for different social groups based on disamenity siting preferences that take into account residential networks. As discussed, disamenities aim to select a location that minimizes the transaction costs associated with the siting process by seeking plots where networks are less likely to mount NIMBY opposition to the siting. We compare the results of location choices based on this criterion under four different types of conceptualizations of network strength. First, the overall size of the network, second the average wealth level of residents within the network, third the proportion of majority residents in the network, and fourth a utility calculation that takes into account each of these network measures.

We test each of these firm-decision mechanisms under two scenarios of residential linking. Under all scenarios, residents have a 60% chance of linking with other residents of the *same* race in their vicinity. We then compare results when residents also have a 20% chance of making a tie with a resident of the *opposite* race with scenarios where residents have a 60% chance of connecting with the *opposite* race.

Table 2: Scenarios Simulated

		Residents: Probability of linking to the same race or other race	
		Same (0.6 for all residents regardless of race)	Different (0.6 for the same race and 0.2 for the different race)
Disamenities: Siting Decision Criteria	Small network size	Scenario 1	Scenario 5
	Low network wealth	Scenario 2	Scenario 6
	Low proportion of majority residents in network	Scenario 3	Scenario 7
	Combination of three factors above	Scenario 4	Scenario 8

ANALYSIS

Our key outcome of interest is the relative level of environmental quality for different social groups. In the model, social groups can be organized in two ways: by racial group and by income level. We tracked these variables across time in the simulations, with each trial running for 70 ticks. We ran a total of 800 simulation trials of 100 trials each of the eight different scenarios, which are listed in Table 2. Thus, data from the model can be conceived as a panel set with 70 time ticks for each of the 800 trials. Taking the average outcomes for all the trials in the eight scenarios leaves a panel of 8 averaged scenarios with 70 time ticks each, displayed in Figures 1 and 2.

As can be seen in both Figures 1 and 2 (both labeled with the scenario numbers listed in Table 2), results across each of the scenarios were unexpected and generally out of line with previous research along similar lines (Eckerd, Campbell, and Kim, 2012; Kim, Campbell and Eckerd, 2013; Campbell, Kim, and Eckerd, forthcoming). In each of the eight scenarios in Figure 1, minority residents lived with overall better environmental quality than majority residents, which in addition to being contrary to previous similar research, also varies from many empirical results. Further, as Figure 2 illustrates, there is very little environmental quality variability across different income groups. If the model were able to accurately mimic observed outcomes, we would expect majorities to have higher levels of environmental quality, and the poor to have the lowest among income groups.

Figure 1: Environmental Quality by Race

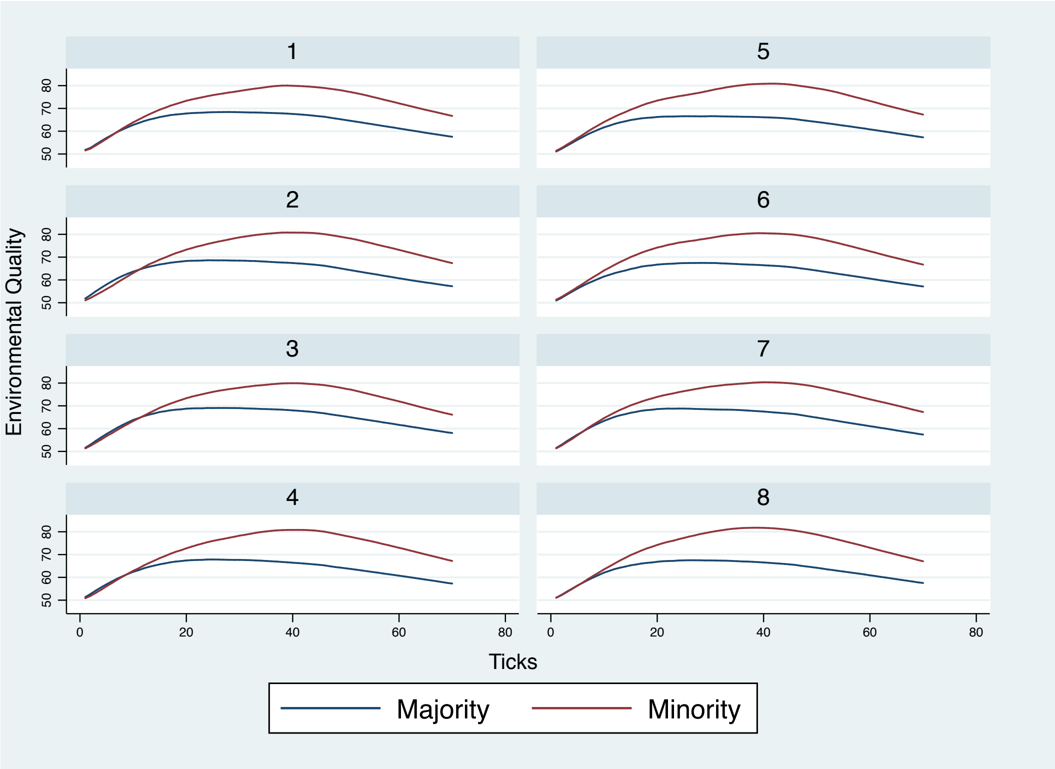
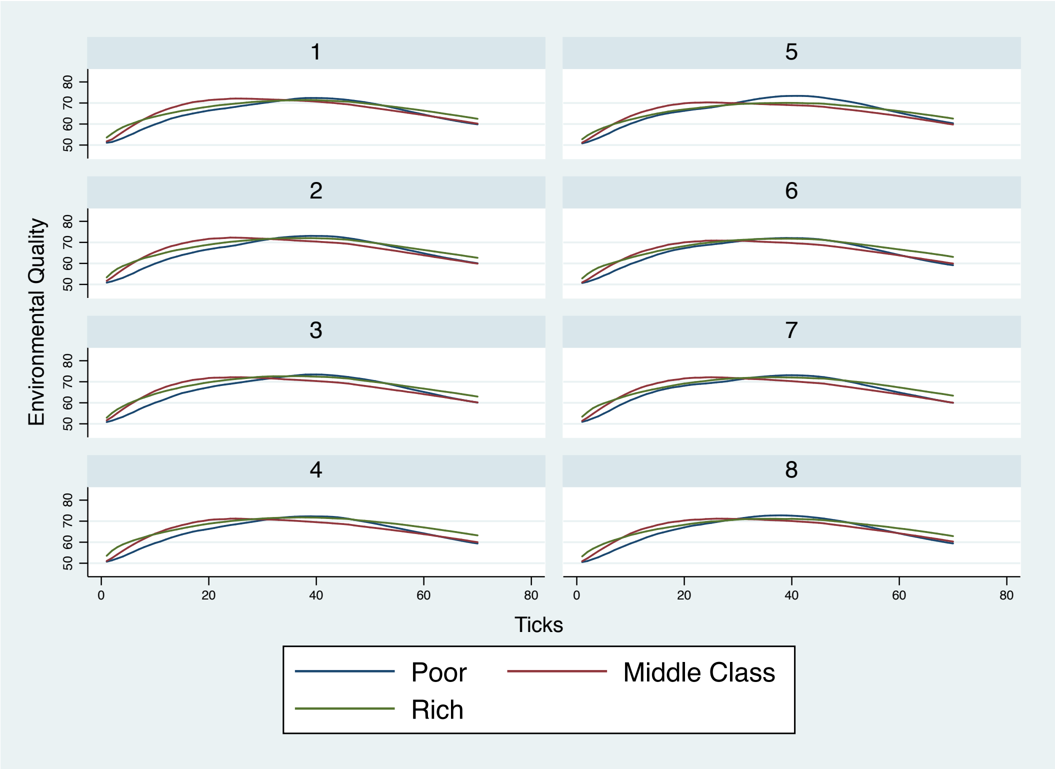


Figure 2: Environmental Quality by Wealth Class



DISCUSSION

These results suggest a couple of conclusions. First, in the modeled outcomes it does not really matter to EJ outcomes *how* disamenities assess the strength of a local network. The results for all scenarios show similar trends both between the two race groups and the three income classes. Although unexpected, this result illustrates a use of ABM – the model was essentially an application of the Coase theorem as it relates to environmental justice (Hamilton, 1995), but the results of the model were not consonant with observed outcomes. There are two possible reasons for this discrepancy: Either the model has not appropriately captured the theory—for example regarding how networks are assessed—or there may be other necessary factors, omitted from the simplified model, that affect the social process.

The results presented in Figures 1 and 2 are best understood by considering the choices that both types of firms use when making location decisions. Since disamenities opt for locations with relatively weaker networks, this leads to siting in two types of locations: either those areas where there are comparatively few residents nearby (i.e., away from populations), or in areas with large proportions of minority residents. This latter result occurs for several reasons, regardless of how we measure network strength. By definition, there are fewer minorities, and the average size of the networks to which minorities belong is consistently lower than for majorities, especially when the two races are less likely to form interracial ties.[6] Minorities are also less wealthy on average, so the networks with larger minority proportions tend to be poorer. Regardless of which network-measure disamenities use, they will tend to locate in minority areas unless they

[6] Recall that in all scenarios there are racial similarity preferences for residents' location choices.

locate away from populations altogether. Further, in the results above, amenities seek the lowest-priced plots; since minorities are, on average, less wealthy than majorities, the areas with large proportions of minorities tend to be poor, thus have low-priced plots, and thus are attractive locations for amenities. It appears that the positive effect of being near amenities is overwhelming the negative effect of being near disamenities.

These results suggest that there may be a problem with our conceptualization of network strength or siting decision factors. Yet, given our reading of the social capital and NIMBY literatures, we believe that the network measures, while perhaps simplified, are consonant with observed trends with respect to which sorts of communities are likely to mount NIMBY opposition and thus increase transaction costs for siting firms. However, in reality disamenities may not necessarily seek the weakest network, but, for production-cost reasons, may instead select a particular geographic area and then assess probabilities for opposition just within that geographic range. Or, perhaps disamenities don't seek the weakest network, but rather just avoid the strongest network. On the other hand, it seems that disamenities tending to locate either away from all populations or in comparatively poor areas is consonant with some observed reality (for example, TSDFs and airports tend to locate outside urbanized areas).

So, we turn our attention to amenities. Amenities may not simply seek the lowest-priced plot upon which to locate. Instead of focusing only on plot price, amenities may seek to locate in areas where social networks are strong, assuming that a strong social network will, while increasing transaction costs for disamenities, reduce amenities' transaction costs. It is also possible that amenities may seek a location based, not solely on price, but also on the characteristics of the labor pool in a particular area.

We explore this last idea further by incorporating a new attribute of residents: education level. Educational level is measured similar to income; each resident is assigned a random number of years of education from a normal distribution. Based on population characteristics from the 2010 US Census, majority residents have an education level from a distribution with mean 14 years and standard deviation 2, while minority residents' mean level is 12 years with a standard deviation of 3. We also then changed the amenity location choice to a simple linear maximization: balancing the lowest-priced plot (as before) with the *highest* average education level of the nearby resident pool.

Varying none of the other parameters from those described above, but including residents' educational levels and amenity firms seeking more-educated neighborhoods, we then find the results presented in Figures 3 and 4. As these figures show, adding resident education levels, and then assuming that amenity firms (low-polluting, job-providing) not only seek low prices but also educated residents nearby, returns the results to those supported by much of the empirical literature: minorities overall do worse on the measure of environmental quality.

The original results described above and then the results shown in Figures 3 and 4 together indicate that a world in which firms behave economically rationally, with all firms seeking the lowest-priced plot but disamenity-producing firms also seeking to locate away from strong social networks in a Coaseian form of rationality, is unlikely to produce an outcome that is environmentally unjust for minorities. Instead, in order to observe minority-based environmental injustice, both types of firms, polluting and nonpolluting, must consider some factor other than the pure economic rationality of cost minimization in their location choices (cf. Eckerd, Campbell, and Kim 2012).

Figure 3: Environmental Quality by Race with Educational Variation

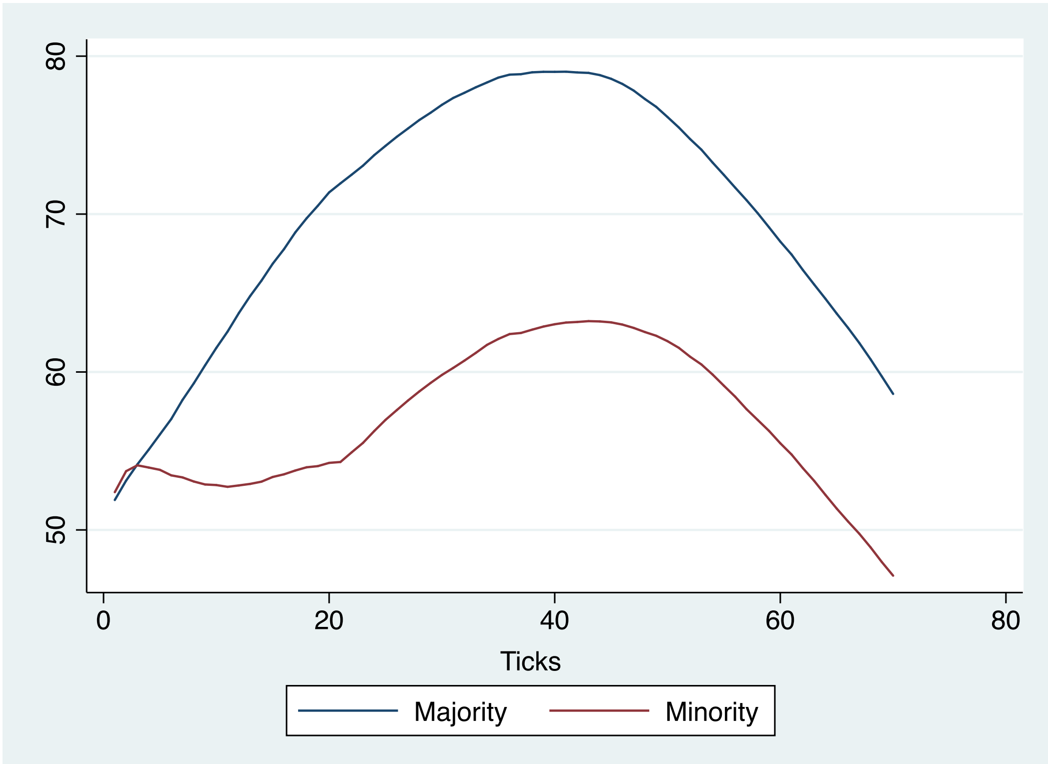
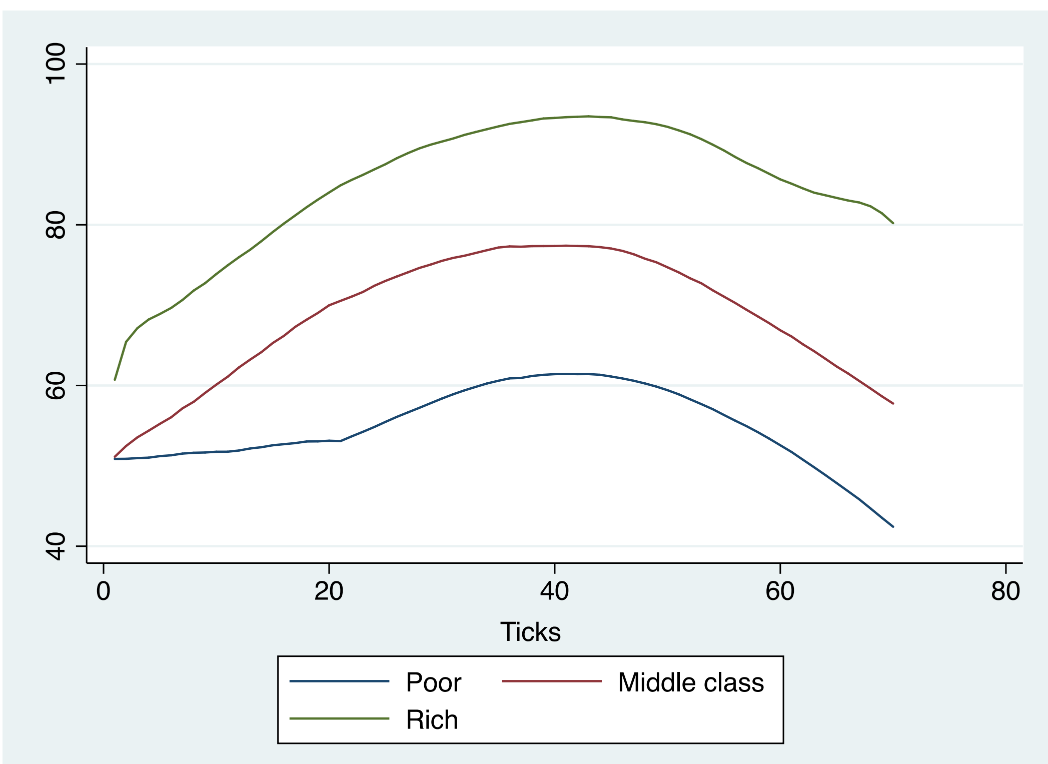


Figure 4: Environmental Quality by Class with Educational Variation



CONCLUSION

In previous research, we explored how firm intentionality, residential choice, and local government policy all affect the extent of environmental disparities between racial groups and economic classes. In this paper, we further this research stream by incorporating concepts of social capital, networks, and NIMBY opposition to the model. We built the model to focus on the assumptions of the Coase theorem. We assume that residents have a propensity to mount political opposition to the siting of an environmental disamenity and that this propensity is determined by the level of social capital that exists within a social network. Drawing from empirical research and group theory, we assume that networks that are larger, have wealthier members, and have more majority members are, as several scholars have assumed, comparatively more likely to mount NIMBY opposition. Because of this, disamenity-firm owners will seek to avoid such opposition because it increases the transaction costs of siting a facility.

In the model, working under these assumptions, we found that minorities tended to live with higher environmental quality than majorities, and that there was little variation in quality levels across economic classes. Given this implausible result—and one which doesn't match much of the empirical literature—we altered the model and reconsidered how low-polluting firms make location choices. When assuming that amenity firms seek highly educated residents in addition to low prices, we saw results that were much more in line with expectations and observed outcomes. To our knowledge, the Coase theorem has only been applied to disamenity locational choices. Our research suggests that the Coase theorem is an insufficient condition (although it may still be useful) to explain the environmental justice problem. Social capital and network strength may matter for repelling hazardous land uses, but they may also matter for attracting desirable land uses. In a complex social system, we need to consider, not just how disamenities make location choices, but also how amenities and residents do as well, and how the aggregation of those choices lead to the social outcomes that emerge.

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