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Environmental Injustice and Residential Segregation: Investigating the Link

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Abstract

Environmental Justice advocates claim that poor and minority communities are disproportionately exposed to environmental hazards. Furthermore, it is asserted that this differential exposure is primarily a product of institutional racism, both past and present, in the siting and management of environmental hazards. Therefore, much of the research into environmental injustice has concentrated on empirically investigating these claims. However, this approach implicitly rules out the possibility that differential exposure may, in part, be a consequence of the formation of communities.

A small handful of empirical papers (Been 1994, Been 1997, Mitchell 1999, Banzhaf and Walsh 2005) have explored the possibility of environmentally induced migration patterns with mixed results. However, to date, researchers have overlooked a potentially important confounding factor in this analysis – the interaction of income, preference for racial composition, and preference for environmental quality. This paper is a first attempt to merge insights from the literature on residential segregation with the possibility of environmentally driven household sorting. The research provides a theoretical analysis of the implications of these interactions. A locational equilibrium model is developed in which households have preferences over both racial composition and environmental quality.

The model is used to investigate whether the interaction between these preferences can lead households to sort in such a way that minorities, controlling for income, are disproportionately exposed to low environmental quality – even in the case where preferences for environmental quality are constant across racial groups and no discrimination is present in the market. The results demonstrate that in the presence of preferences for racial composition, it possible to support, in equilibrium, a distribution that reflects what would traditionally be labeled as environmental injustice. However, this equilibrium is supported independent of the siting of environmental hazards and independent of any form of direct discrimination. It is supported simply by the introduction of racial preferences.

The findings also suggest that the initial distribution of households (at the time of siting) may be a critical factor in explaining the currently observed distribution. Furthermore, the model and results highlight the potential significance of population proportions, neighborhood size, and number of neighborhoods within a household's locational choice set.

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I. Introduction

Environmental Justice advocates claim that certain demographic groups are disproportionately exposed to environmental hazards. Of particular concern is the potentially "inequitable" burden across race and income. This claim has received considerable attention, especially from groups that believe it is a social inequity that should be addressed. The US Environmental Protection Agency (EPA) has recognized the social importance of environmental justice through the creation of the Office of Environmental Justice in 1994. This office works towards achieving "environmental justice" such that "everyone, regardless of race, culture, or income, enjoys the same degree of protection from environmental and health hazards" (Whitman (2001)). This mission has clear implications for both current and future policy.

The political and social attention has also led to a significant literature that addresses various questions related to environmental justice. Research into this claim can be grouped into three strands: (1) characterization of the *current* distribution of environmental hazards and demographic groups (characterization), (2) investigation into the distribution of demographic groups at the *time of siting* (siting), and (3) explaining and investigating migratory patterns between the time of siting and the present (market dynamics).

Characterization is an empirical exercise, which on the surface appears to be straightforward, but is actually quite complex. There is a continuing debate related to the appropriate empirical model as well as the best use of the existing data. While the full extent of environmental "(in)justice" is not entirely agreed upon, there is general consensus that, to some extent, minority and poor communities currently are exposed to higher levels of environmental hazards.

However, even if the current distributions indicate some level of inequity, the relationship between the distribution of hazards and households must be viewed as an endogenous process. On one hand, the selection of the location for environmental hazards may be a function of the demographic characteristics of a community. Alternatively, household behavior in the selection of a location may be a function of community environmental quality and related consequences (i.e., effects on property values). Accordingly, in the presence of endogeneity, observations on the current distribution lack the explanatory power needed to identify sources of the perceived inequity.

Two approaches, derived from different definitions of environmental justice, have emerged to address this issue. The first approach contends that environmental justice issues are fundamentally concerned about inequities in the siting of hazards. The siting literature is actually quite similar to that of characterization. Yet, instead of investigating current distributions, the empirical studies focus on the distributions at the time of siting. While this approach suffers from some of the same empirical issues as the literature on characterization, there are two improvements. First, in theory, the problem of endogeneity is overcome by making the reasonable assumption that the distribution of demographics is exogenous at the time of siting. Secondly, this literature offers guidance for policy in the siting of hazards; therefore, directly addresses environmental justice.

Alternatively, the second approach is based on the premise that environmental justice is concerned not only with siting but also with the current inequity. Thus, addressing environmental justice issues requires an understanding of the dynamics that lead to the current distributions. Specifically, this strand of research is interested in the other endogenous process: how household behavior impacts the distribution of demographics following the siting of environmental hazards. The most common motivation for this research is based on the potential role of income. Typically, a qualitative argument is constructed following the logic that the introduction of an environmental hazard will cause a reduction in property values. Consequently, an expected outcome is for rich individuals to move out (or avoid) and poor individuals to move in (or stay).

To date, this line of research has focused on identifying the existence of migratory behavior. Generally, the findings support this theory of "market dynamics." However, the literature has yet to investigate the preferences that lead to the current distribution of demographics. More so, while the discussion focuses almost entirely on income, the characterization literature has provided general evidence that even when researchers control for income, minorities are still found to bear a greater burden. This finding suggests that pure income effects cannot fully explain the dynamics leading to observed distributions.

In this paper, a simple locational equilibrium model is developed to demonstrate how interactions between racial preferences, environmental preferences, and income can give rise to these observed patterns of exposure to environmental hazards – even when tastes for environmental quality are identical across all groups. Specifically, the analysis demonstrates that equilibrium market outcomes exist for which tastes for racial composition lead whites and blacks of identical income and tastes for environmental quality to consume disparate levels of environmental quality.

While the primary purpose of this research is to consider the role of tastes for racial composition in an environmental justice context, it is important to note that the findings can be generalized to a wide variety of local public goods. Specifically, the distribution of other local public goods (i.e., school quality, level of crime, etc.) across demographics may be, in part, impacted by tastes for racial composition.

These findings highlight the importance of recognizing the role of household self-selection by race for both policy and empirical research related to the distribution of local public goods. For example, empirical models that attempt to recover preferences or demand for local public goods across race may lead to incorrect inferences if tastes for race are not accounted for in the specification of model.

While this observation has not been directly investigated in an environmental justice context, Bayer et al. address this specific issue in a series of recent empirical papers including Bayer et al. (2003) and Bayer et al. (2005). They generally find evidence that race plays a role in household locational choice around local public goods. For example, in Bayer (2005), it is found that black households appear to trade off between highly educated and highly black neighborhoods. These findings are consistent with the predictions offered in this paper.

The remainder of the paper proceeds as follows: Section II discusses the relevant literature. The model is introduced and analytical results are discussed in Sections III. The computational strategy and numerical results are presented in Sections IV. Section V provides two applications of the model. Finally, Section VI provides a summary and conclusion.

II. Related Literature

Over the past three decades a large number of environmental justice studies have characterized the link between community composition and the presence of environmental hazards. These studies typically estimate a reduced form model regressing indicators of environmental quality on various demographic characteristics. While a handful of studies have found no link between demographics and the presence of environmental hazards (notable examples include Anderton (1994), Atlas (2002), Taquino (2002)), most studies suggest a significant relationship (notable examples include GAO (1983), Lee (1987), Mohai and Bryant (1992), Bowen (1995), Boer (1997), Daniels (1999), and Banzhaf and Walsh (2005)). Furthermore, race is often found to be a significant predictor of environmental quality even when controlling for income (Lee (1997), Mohai and Bryant (1992), Been (1997), Boer (1997), and Banzhaf and Walsh (2005)). Generally, studies that find evidence of a link concentrate on smaller geographical areas; whereas, studies that consider the US as a whole often find little or no evidence of these correlations.

As a result of these studies, there is a general consensus that poor and minority communities, are at least to some degree, exposed to differentially lower levels of environmental quality. Consequently, there has been significant social pressure to address these "inequities" (see Bullard (1990) and EPA (2004)). However, effective policy requires an understanding of how and when differential exposure levels arise. Due to the complicated nature of the relationship between environmental quality and community composition, these studies are limited in what they reveal regarding causal mechanisms.

Investigating the demographics at the time of the siting of environmental hazards is one approach that has been used to uncover causation and explain effective channels for policy. Interestingly, these studies often find race and income to be less significant in predicting siting decisions (two notable exceptions are Been (1994), Brooks and Sethi (1997)). The most significant demographic characteristic is the level of collection within a community (Hamilton (1993, 1995, 1999), Arora and Carson (1996), and Wolverton (2003)). This finding provides guidance to address inequities in the siting of environmental hazards. However, these findings, in conjuction with the currently observed distributions, implicitly suggest that over time low income and minority groups appear to have disproportionately migrated into these communities.

These results have motivated a handful of studies to formally investigate migration following the siting of environmental hazards (Been (1994, 1997), Mitchell (1999), Banzhaf and Walsh (2005)). In general these studies find evidence supporting the existence of migratory behavior. Specifically, the proportion of poor and minorities is found to increase over time in communities with environmental hazards. Therefore, even if inequities at the time of siting are addressed, the composition of these communities over time may still reflect environmental "injustice" as a result of migratory behavior.

Identifying and understanding the factors that lead to this specific migratory behavior is ultimately needed if issues of environmental justice are to be accurately characterized. To date, only qualitative discussions of potential factors have been offered. For example, Been (1994) contends that the introduction of an undesirable environmental hazard is likely to cause property values to decrease as well as cause wealthier households to move away. She suggests that as a consequence of these lower property values, lower income households are likely to move into the neighborhood. However, evidence also demonstrates disproportionate migration of minorities, even when controlling for income. Been and Gupta (1997) suggest that "the decrease in property values would then make the neighborhood's housing more affordable…for those whose housing choices were limited by racial discrimination in the residential housing market." However, the relationship between more affordable housing (as a result of reduced environmental quality) and housing discrimination is not as straightforward as the discussion regarding income effects. In general, within the environmental justice literature, this issue has received little attention or explanation.

The purpose of this paper is to theoretically model household locational choice in an environmental justice context. This approach is motivated by the important role both household income and race are likely to have in locational choice. It is especially critical to consider the role of race since, to date, the intuition needed to explain the disproportionate movement of minorities towards communities with environmental hazards is unclear. To this end, a locational equilibrium model is constructed. The approach models the role that household preferences for racial composition and environmental quality play in determining the different types of demographic patterns that can be supported in a market equilibrium. To model the effect of race on household choice I draw from findings in the residential segregation literature. This literature offers three primary explanations for the observed heterogeneity in the locational choice of households of difference races: differences in income; discrimination; and racial (and race related) preferences.

Differences in income is an unambiguous and straightforward factor that effects locational choice. Minority status is correlated with lower income. Thus, minorities are overrepresented in low income communities.[1] However, studies have demonstrated that levels of observed residential segregation exceed the distributions that would be expected if income was the only factor affecting racial housing locations (see for instance Bayer et al. (2004)).

Discrimination was historically a significant factor impacting locational choice (Denton and Massey (1994)). Anti-discriminating reforms in the housing market were first introduced with the adoption of the Fair Housing Act of 1968. While the existence of discrimination in the housing market did not immediately disappear, the level was significantly reduced and continued to diminish in subsequent decades. However, discriminatory practices are believed to continue to play a role in racial locational choice.[2]

The literature related to racial preferences is vast. One strand of the literature utilizes surveys in an attempt to uncover racial preferences (Farley et al. (1978, 1994, 1997), Bob and Zubrinsky (1996), and Emerson et al. (2001)). Alternatively, several researchers have theoretically modeled and empirically tested the role of racial preferences in the housing market (Schelling (1973), Yinger (1976), Clark (1991), King and Mieszkowski (1999), and Bayer et al. (2002 and 2004)). Taken together these

[1] Denton and Massey (1994) provides a nice discussion of these findings.
[2] Two relevant studies published by the US Department of Housing and Urban Development (HUD) include Housing Discrimination Study 2000 and All Other Things Being Equal: A Paired Testing Study of Mortgage Lending Institutions (April 2002).

studies provide substantial evidence that racial preference contribute to observed differences in the locational choice across race. Specifically, evidence exists that suggest that households generally have a preference to live with other households of the same race.

The model developed in this paper incorporates difference in income and racial preferences. To bring these factors into an environmental justice context, the interaction of environmental preferences is also included in the model. This interaction has yet to be investigated in the environmental justice literature. Furthermore, considering the role of racial preferences in this context reaches entirely outside the current scope of issues considered in this literature. The analysis provides insight into why these observed patterns of race and environmental quality may arise – specifically highlighting the potential importance of household self-segregating behavior.

III. The Model and Analytical Results

The model considers a two region (j = 1,2) economy. Individuals differ by income and race. Assume two possible income groups, high income and low income ($m = H, L$). In addition, assume two possible racial groups, white and black ($r = w, b$). Together this heterogeneity results in four possible types: rich white (w_H), poor white (w_L), rich black (b_H), and poor black (b_L). The population is exogenously known and equal to $\mathrm{N} = \sum_{i=w_H,w_L,b_H,b_L} \sum_{j=1}^{2} \mathrm{n}_{ij}$, where n_{ij} represents the number of individuals of type i situated in region j. In addition, define N_1, N_2 as the total population residing in region 1 and 2; respectively, and N_w, N_b as the total number of whites and blacks in the economy; respectively.

Each of the two regions consists of an equal amount of homogeneous land (hereafter, housing stock). The quantity of housing stock in each region is specified as $k_1 = k_2 = k$. These regions are differentiated by the exogenously set environmental quality of the region and by the endogenously determined racial composition.

Individuals choose region 1 or 2 to maximize their utility, given by:

$U = f(x,l,R,g)$ where,

x = composite good
l = land consumption (i.e., lot size)
R = perceived racial quality
g = environmental quality

subject to a simple budget constraint,

$y_i = x_i + p_j l_{ij}$, where

y_i = income of individual of type i
p_j = price of land
$p_x = 1$.

For tractability, *f(x,l,R,g)* is assumed to be Cobb-Douglas:

$U_{ij} = x_i^{\alpha} l_{ij}^{\beta} R_{rj}^{\eta} g_j^{\gamma}$ where, $\alpha + \beta = 1$; α, β η, $\gamma > 0$

For simplicity, I further assume that households consume a fixed lot size and normalize land consumption to 1.[3]

This specification gives rise to the following conditional indirect utility function:

$$V_{ij} = (y_i - p_j)^{\alpha} R_{rj}^{\eta} g_j^{\gamma}$$

The role of environmental quality is determined by both the state of quality within region j (g_j) and each individual's preference for quality (γ). To isolate the interaction

[3] The model has been tested with this assumption relaxed, and it should be noted that while the results from the two models are not perfectly comparable, the fundamental conclusions are the same.

between race and income, environmental preferences are assumed to be constant across types.

The importance of perceived racial quality is determined by the combination of racial quality (R_{rj}) and the parameter, η. This parameter captures the relative importance for racial quality. To define perceived racial quality, begin by specifying C_{rj} as the fraction the population residing in region j that is of racial type r:

$$C_{rj} = \frac{n_{rj}}{\sum_{r=w,b} n_{rj}}$$

Then, the racial quality perceived by an individual of race r in region j is defined as:

$$R_{rj} = 1 - \left(D_r - C_{rj}\right)^2, \quad R \in (0,1)$$

where,

D_r = racial bliss point

Racial quality is an endogenously determined component of the utility function intended to capture racial preferences. The bliss point of race r represents the ideal fraction of race r's racial group residing in a particular region (or community). As the actual composition of the region deviates from the bliss point, the individual experiences some disutility. Observe that racial quality is maximized ($R = 1$) when the racial composition is equal to the bliss point ($D_r = C_{rj}$).[4]

The model developed above can easily be generalized to include additional regions and types. Furthermore, types could be defined not only by race and income but

[4] A more general, and much less tractable, functional form was tested in the model that allowed disutility to be asymmetric around the bliss point. Specifically, an individual was better off if the individuals moving in were of the same race. The model was generally insensitive to this alternative specification.

also by racial preference and environmental preference – creating additional heterogeneity. However, the model analyzed in the paper provides the necessary insight to show the potential implications of the interaction of racial and environmental preferences.

Equilibrium is an allocation of prices and individuals across regions such that the following conditions are satisfied:

EQ1. No individual of type $i, \forall i$, could be made better off by moving to another region:

$$V_{ij} \geq V_{ik} \text{ if } \mathrm{n}_{ij} > 0 \text{ and } \mathrm{n}_{ik} = 0$$

$$V_{ij} = V_{ik} \text{ if } \mathrm{n}_{ij}, \mathrm{n}_{ik} > 0$$

EQ2. Every individual must be living in one of *r* regions (no one is homeless):

$$\sum_{j=1,2} \mathrm{n}_{wj} = \mathrm{N}_w \text{ and } \sum_{j=1,2} \mathrm{n}_{bj} = \mathrm{N}_b$$

EQ3. The housing market clears: land demand equals supply (all land is occupied):[5]

$$\sum_{i=w_H, w_L, b_H, b_L} \mathrm{n}_{i1} = k_1 \text{ and } \sum_{i=w_H, w_L, b_H, b_L} \mathrm{n}_{i2} = k_2$$

Given the above specification and conditions for equilibrium, I proceed with an analytical analysis of a simple model consisting of two types: rich white and poor black. To evaluate the model, I first identify the different possible distributions of types across regions and then determine if these distributions represent a supportable equilibrium.

[5] Observe that in order to clear the housing market, each "unit of land" requires a "unit of an individual." This relationship is an implication of normalizing lot size. Furthermore, since lot size is fixed to 1, the total land stock available must equal the total population. In addition, the proportion of each type will dictate the possible distributions across regions. For example, suppose each region consists of *x* lots, and the populations consists of *x*+1 whites and *x*-1 blacks. In order to clear the market, the white population must reside in both regions. It should also be noted that integer populations are not required.

Further, I assume that the proportion of rich whites (n_w) exceeds that of poor blacks (n_b).[6] Under these assumptions, the set of possible equilibria are given in Table 1.

TABLE 1: Two Type Model – Possible Equilibria			
Case	*Description*	*Distribution*	*Equilibrium Condition EQ1*
INT	Integration in both regions	$n_{ij} > 0 \;\; \forall \, i, j$	$V_{w1} = V_{w2}$ and $V_{b1} = V_{b2}$
SEG1	Partial Segregation – poor blacks in region 2 (*j*2) only	$N_1 = n_{w1}$ and $N_2 = n_{w2} + N_b$, where $n_{wj} > 0 \;\; \forall j$	$V_{w1} = V_{w2}$ and $V_{b1} \leq V_{b2}$
SEG2	Partial Segregation – poor blacks in region 1 (*j*1) only	$N_1 = n_{w1} + N_b$ and $N_2 = n_{w2}$, where $n_{wj} > 0 \;\; \forall j$	$V_{w1} = V_{w2}$ and $V_{b1} \geq V_{b2}$

Observe that the equilibria are formally differentiated by the first equilibrium condition (*EQ1*). While the second equilibrium condition (*EQ2*) and third equilibrium condition (*EQ3*) must hold in equilibrium, the relationship derived from *EQ1* will primarily drive the results. Furthermore, observe that since the rich white represent a majority of the population, in order for the land market to clear, whites must live in both regions.

First, some general remarks can be made regarding potential outcomes. For instance, suppose the environmental quality in region 1 is greater than in region 2 ($g_1 > g_2$). If $n_{b1} < n_{b2}$, then individuals have sorted in such a way that the black population is observed to bear a disproportionate burden of "low environmental quality." This outcome is possible under the integrated equilibrium (*INT*) and is a defined implication of the second segregation equilibrium (*SEG2*). Investigating the conditions for existence of these equilibria provides insight into the impact of individual behavior. To isolate the

[6] It is assumed throughout the paper that the white population exceeds that of the black population, an assumption that is consistent with the observed population in the US.

role of racial preferences, the model is solved both with and without the presence of racial preferences. The model without race is in some sense a control. It demonstrates the pure income effects on individual behavior when sorting between communities with heterogeneous environmental quality.

Analytical Results: Two Type Model <u>without</u> Racial Preferences

Begin by considering the integrated equilibrium. For integration, both populations will be represented within each region. Therefore, for condition *EQ1* to be satisfied, the following equality must hold for both types:

$$V_{r1} = V_{r2} \tag{V.1}$$

$$(y_r - p_1)^{\alpha} g_1^{\gamma} = (y_r - p_2)^{\alpha} g_2^{\gamma}$$

Rearranging the above relationship, an expression for price in $j2$ can be recovered:

$$p_2 = y_r - (y_r - p_1)G \text{ where } G = \left(\frac{g_1}{g_2}\right)^{\frac{\gamma}{\alpha}} \tag{V.2}$$

Observe, if $g_1 = g_2$, then the price in each region must be equal for the population to be indifferent.

Expanding V.2 by race (type) and defining p_{rj} as the indifference price for race r within region j, the two equalities for equilibrium are:

$$p_{w2} = y_w - (y_w - p_1)G \tag{V.3}$$

$$p_{b2} = y_b - (y_b - p_1)G \tag{V.4}$$

Differentiating V.4 and V.5 with respect to G demonstrates how the indifference price (p_{r2}) for each race responds to changes in environmental quality:

$$\frac{dp_{w2}}{dG} = p_1 - y_w \tag{V.5}$$

$$\frac{dp_{b2}}{dG} = p_1 - y_b \tag{V.6}$$

By definition, income will exceed price in $j1$. Therefore, for $p_1 = \overline{p}_1$ and a marginal increase in G, the decrease in p_2 required to maintain indifference across regions is larger for the white population. Specifically, with $y_w > y_b$, the black population would be willing to pay more for $j2$. Therefore, in the absence of a common indifference price in $j2$ between the white and black population, this distribution cannot be supported in equilibrium.

The intuition is as follows: in the absence of price, both types will prefer $j1$ (high environmental quality) to $j2$ (low environmental quality). The only channel to achieve indifference between the two regions is through relative price. However, due to income differences, the indifference price gap for the wealthier population will exceed that of the poorer population.

Now consider the partially segregated equilibria with the poor black population living entirely within one region (*SEG1* and *SEG2*). Without loss of generality, I assume that g_1 exceeds g_2 and thus $G > 1$. The *SEG2* equilibrium, under which the black population resides entirely in $j1$, will be evaluated first. From condition *EQ1*, the following relationship must hold for the black population:

$$V_{b1} \geq V_{b2} \tag{V.7}$$

implying:

$$p_2 \geq y_b - (y_b - p_1)G \tag{V.8}$$

The white population will reside in both regions, requiring:

$$p_2 = y_w - (y_w - p_1)G \qquad \text{(V.9)}$$

By setting $p_1 = \overline{p}_1$, p_2 can be recovered such that the white population would be indifferent between the two regions.[7] By substituting for p_2 in equation V.8 from equation V.9, the following result can be recovered:

$$y_w - (y_w - \overline{p}_1)G \geq y_b - (y_b - \overline{p}_1)G$$

$$y_w(G-1) - G\overline{p}_1 \leq y_b(G-1) - G\overline{p}_1$$

$$y_w \leq y_b$$

This result is a contradiction since the white population is wealthier than the black population. Therefore, this equilibrium is not supportable. Intuitively, if prices are such that rich whites are indifferent between the low and high environmental quality communities then poor blacks will prefer the low environmental quality community.

Finally, consider equilibrium *SEG1* under which the black population lives entirely in *j*2. The analysis mimics that of equilibrium *SEG2*. The only difference is the inequality in *EQ1* for the black population is reversed:

$$p_2 \leq y_b - (y_b - \overline{p}_1)G \qquad \text{(V.10)}$$

The equilibrium prices determined to satisfy *EQ1* for the white population remains the same. Therefore, equilibrium is supported if the following holds:

$$y_w - (y_w - \overline{p}_1)G \leq y_b - (y_b - \overline{p}_1)G$$

$$y_w \geq y_b$$

Since this inequality holds, as long as equilibrium conditions *EQ2* and *EQ3* are satisfied, then this is a supportable equilibrium. In equilibrium, the white population is

[7] A unique combination of prices is not recovered in equilibrium. Therefore, the price in one region must be fixed. Throughout the paper price in *j*1 will be fixed.

indifferent between regions and the black population prefers *j*2. Intuitively, the price gap just offsets the difference in environmental quality for the rich white population, but is too large for the poor black population – leading them to choose *j*2.

Thus, without racial preferences, the only equilibrium that can be supported in the two type model is one in which the wealthy occupy the high environmental quality region whereas the poor occupy the low environmental quality region. This finding is consistent with the literature, specifically research that considers vertically differentiated sorting models (Epple 1984). Next, I introduce racial preference to the model.

Analytical Results: Two Type Model <u>with</u> Racial Preferences

First consider equilibrium *SEG1* under which with the poor black population lives entirely in the *j*2. This is the only supportable equilibrium in the absence of racial preferences (when g_1 is assumed to be greater than g_2). Conditions for equilibrium remain the same as above; however, with the introduction of racial preferences, the indifference relationship for the white population becomes:

$$(y_w - p_1)^\alpha R_{w1}^\eta g_1^\gamma = (y_w - p_2)^\alpha R_{w2}^\eta g_2^\gamma \tag{V.11}$$

$$p_2 = y_w - (y_w - p_1) R_w G \text{ where } R_w = \left(\frac{R_{w1}}{R_{w2}}\right)^{\frac{\eta}{\alpha}}; G = \left(\frac{g_1}{g_2}\right)^{\frac{\gamma}{\alpha}} \tag{V.12}$$

Observe that the indifference price between regions now depends on both environmental quality and perceived racial quality, with perceived racial quality varying by race. For instance, if *j*1 has higher environmental quality and more favorable perceived racial quality, then, in equilibrium, p_2 is unambiguously less then p_1. However, if *j*1 has higher environmental quality but less favorable perceived racial quality, then the two effects will move price in *j*2 in different directions. Ultimately, the indifference price is determined by the white population and will depend on the *overall* perceived quality across regions.

Furthermore, observe that by assuming the population distribution across types and regions, the perceived racial quality is predetermined. Specifically, for equilibrium *SEG1* the entire black population is fixed in *j*2 and the white population occupies the remaining land as well as *j*1 entirely. Thus, R_{w1}, R_{w2}, R_{b1}, and R_{b2} are known. Consequently, at $p_1 = \bar{p}_1$, a unique p_2 will satisfy V.12 since all variables are known. With the addition of racial preferences, equilibrium condition *EQ1* for the black population becomes:

$$(y_b - p_1)^{\alpha} R_{b1}^{\eta} g_1^{\gamma} \le (y_b - p_2)^{\alpha} R_{b2}^{\eta} g_2^{\gamma} \qquad \text{(V.13)}$$

$$p_2 \le y_b - (y_b - p_1) R_b G \ \text{ where } \ R_b = \left(\frac{R_{b1}}{R_{b2}} \right)^{\frac{\eta}{\alpha}} \qquad \text{(V.14)}$$

Again, substituting the recovered price (p_2) from condition *EQ1* for the white population:

$$y_w - (y_w - \bar{p}_1) R_w G \le y_b - (y_b - \bar{p}_1) R_b G \qquad \text{(V.15)}$$

Following the introduction of racial preferences the two types now have a unique perception or rank of the overall quality across regions. This heterogeneity complicates the evaluation of the above inequality. Specifically, without a specified racial bliss point and population distribution, the overall perceived quality across regions for each type is unknown. Therefore, the outcome of the above relationship cannot be determined for certain. However, under some basic assumptions, general conclusions can be drawn.

Begin by assuming that both racial groups prefer living in communities with at least half of the households being of the same race (i.e., both racial groups have a racial bliss point exceeding 0.5). Since the entire black population is living in $j2$, the racial quality perceived by the black population is unambiguously more favorable in this region. Alternatively, for the white population, without knowing the exact population distribution, the relative perceived racial quality is unknown. Since the white population lives in both regions, depending on the functional form assumption for perceived racial quality, it is possible for either region to have more favorable perceived racial quality. However, if the racial bliss point for the white population is assumed to be relatively high, then $j1$, an entirely white region, will always have a high level of perceived racial quality. Therefore, even if the racial quality is more favorable in $j2$, the relative difference is unlikely to significantly impact the white population's overall ranking of the regions.

This observation has an important implication when thinking about residential segregation. It suggests that population proportions may be integral in ultimately determining the impact of racial preferences for certain types. Specifically, for the majority population, it may be possible that no matter how the population sorts across regions, the perceived racial quality may never be too "unfavorable." If the majority racial group prefers living with their own race, then the more the economy is dominated by that race, the more likely that race can find a region with favorable perceived racial quality. With this discussion in mind, revisit the above inequality.

Suppose the racial quality in $j1$ is preferred by the white population. In this case, this distribution is clearly supportable. For the white population, compared to this distribution in the absence of racial preferences, the overall quality is even more favorable in $j1$. Therefore, for indifference, the price gap determined by the white population will be even larger. Furthermore, for the black population, relative to before, the overall quality shifts toward $j2$. Combining these results with the rich white population's higher willingness to pay for environmental quality, it is clear that the black population will be better off in $j2$.

The results are not as clear if the racial quality in $j2$ is also preferred by the white population. In this case, for both the white and black populations, the overall quality shifts towards $j2$. However, as mentioned above, the racial quality gap perceived by the white population is likely to be small; especially, when compared to the gap perceived by the black population. Therefore, it is likely that the white population will not only continue to perceive the overall quality in $j1$ to be higher, but also unambiguously favorable when compared to the black population's ranking. Thus, even if the white population reverses[8] their ranking in favor of $j2$, this distribution is likely to remain stable as a result of the significantly larger racial quality gap perceived by the black population.[9]

Now, consider the equilibrium with the black population residing entirely in $j1$ (*SEG2*). The white population will reside in both regions resulting in the same condition as above:

$$p_2 = y_w - (y_w - p_1)R_w G \tag{V.12}$$

The equilibrium condition *EQ1* for the black population is reversed:

$$p_2 \geq y_b - (y_b - p_1)R_b G \tag{V.16}$$

[8] Since the perceived racial quality gap is expected to be small, this reversal will depend on the relative magnitude between the preference parameters on race (η) and environment (γ).

[9] While unlikely, the possibility of this distribution becoming unsupportable cannot be ruled out. Since the rich white population has a higher marginal willingness to pay for each attribute, even if the perceived racial quality gap is larger for the black population, it is possible that the indifference price for the white population would outbid the black population. However, this result would require preferences to not only significantly favor race over environment, but also for the white population to have a relatively strong taste for some integration.

$$y_w - \left(y_w - \overline{p}_1\right) R_w G \geq y_b - \left(y_b - \overline{p}_1\right) R_b G \qquad \text{(V.17)}$$

With the presence of racial preferences, it is now possible to support this distribution in equilibrium. The analysis is again complicated by the uncertainty over how relative racial quality is perceived by the white population. Assume $j1$ (the community with a smaller proportion of the white population) to have higher perceived racial quality for whites and continue with the assumption that $j1$ is the higher environmental equality region implying $G>1$.

Observe that the role of environmental quality depends on the magnitude of the environmental quality gap (g_1 vs. g_2) as well as the preference parameter γ. Similarly, role of race depends on the magnitude of the perceived racial gap (R_{r1} vs R_{r2}) as well as the preference parameter η. In general, it follows that if the racial tastes are relatively strong in comparison to environmental tastes, then this equilibrium with the poor black population living in the high environmental quality region may be supportable. In addition, the perceived racial quality gap for the black population $\left(\frac{R_{b1}}{R_{b2}}\right)$ must be relatively larger than the white population $\left(\frac{R_{w1}}{R_{w2}}\right)$. The indifference price decided by the white population will reflect both higher environmental quality and perceived racial quality in $j1$. Therefore, to be better off in $j1$, the perceived racial quality gap for the black population must be significant enough to compensate for the relatively high price in $j1$.[10]

[10] Note that if the white population perceives racial quality to be more favorable in $j2$, support for this distribution becomes stronger. Furthermore, equilibrium *SEG1* will also always be supportable when this equilibrium (*SEG2*) is supportable.

Finally, consider the integrated distribution (*INT*). Both the white and black populations must be indifferent between regions, resulting in the following conditions from *EQ1*:

$$p_2 = y_w - (y_w - p_1)R_w G \tag{V.12}$$

$$p_2 = y_b - (y_b - p_1)R_b G \tag{V.18}$$

Observe that these conditions represent two equations and two unknowns.[11] Therefore, this equilibrium can be directly calculated by solving the following equality:

$$y_w - (y_w - \overline{p}_1)R_w G = y_b - (y_b - \overline{p}_1)R_b G = p_2 \tag{V.19}$$

For $p_1 = \overline{p}_1$ and $g_1 > g_2$, it is now possible to recover a unique p_2 such that both racial groups are indifferent between regions. In the absence of racial preferences it was shown that the wealthy white population will always have a higher willingness to pay for environmental quality. Therefore, in order for this equilibrium to exist, the perceived racial quality gap for the black population must both favor the high environmental quality region and exceed the gap perceived by the white population.. Thus, in equilibrium, there is not only a unique p_2, but a unique distribution.

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[11] R_w and R_b are both a function of population compositions across regions. Therefore, if the composition of one race is known, the other can be recovered. Specifically, consider the expression for the white population's relative perceived racial quality: $R_w = \dfrac{R_{w1}}{R_{w2}} = \dfrac{1 - \left(D_w - \dfrac{n_{w1}}{\sum_{r=w,b} n_{r1}}\right)^2}{1 - \left(D_w - \dfrac{n_{w2}}{\sum_{r=w,b} n_{r2}}\right)^2}$. Observe that with fixed land consumptions, $\sum_{r=w,b} n_{r1}$ and $\sum_{r=w,b} n_{r2}$ are known. Also, recall that N_w and N_b are exogenously specified in the model. Thus, if n_{w1}, n_{w2}, n_{b1}, or n_{b2} is known, all others can be recovered and both R_w and R_b can be solved.

This equilibrium is highly unstable. A marginal change in environmental quality or population compositions will cause the model to tip to one of the other two equilibria. Specifically, with any marginal change, the indifference prices for both populations will deviate from indifference prices observed prior to the change. Therefore, the high income white population will outbid the low income black population for the region with improved overall quality. This behavior will continue until a stable segregated equilibrium is reached.

Comparing the analytical results under models with and without racial preferences highlights the potential importance of accounting for taste for racial composition when evaluating questions of environmental justice. Specifically, in the presence of racial preferences, household locational choice may deviate from traditionally expected outcomes in which households stratify by income. Furthermore, the analysis suggests that population proportions may play an important role. For minority populations it is likely that community choice could be highly constrained such that choices may be limited to either communities with the high levels of environmental quality *or* high levels of racial quality. Alternatively, the majority population may observe high levels of racial quality in a much larger set of communities with varying levels of environmental quality.

IV. Numerical Simulations

In order to gain further insights into the workings of the two type model and to allow for the consideration of a richer set of household types, it is useful to develop a numerical version of the analytical model. I start with a parameterized version of the simple two type model and then move to a model with four types. Table 2 presents the parameter values that are used in the first set of simulations:

TABLE 2: Parameterization of the 2-Type Model		
	Type	
	w_H	b_L
Pop. (n_i)	1.7	0.3
income (y_i)	1	0.67
Bliss (D_r)	0.8	0.8
	Region 1	Region 2
Capital stock (k)	1	1
Environmental quality (g)	2	1
Composite (α)	0.7	
Environ. (γ)	0 - 0.3	
Race (η)	0 - 0.3	

As discussed above, the relative effects of environmental and racial tastes will play an important role in determining if a distribution is supported in equilibrium. Furthermore, determining the appropriate magnitudes in the context of this model is arbitrary since there is no precedent for relative taste for race and environmental quality. This key interaction in the model will be investigated by varying the preference parameters η and γ. The analysis allows preferences to range from $\eta, \gamma = 0$ to $\eta, \gamma = 0.3$.

The population is assumed to consist of 85% (1.7) white and 15% (0.3) black. This selected population distribution is consistent with the approximate observed proportions of white and black populations in the US. Table 6 below provides some basic (approximated) statistics from the 2000 Census:

TABLE 3: Distribution of Population (Source: US Census)				
	White-Black Pop.		*Total Population*	
Geographical Area	*White*	*Black*	*White*	*All Other*
US	85%	15%	75%	25%
Atlanta MSA	70%	30%	65%	35%
Boston-Worcester-Lawrence CMSA	94%	6%	85%	15%
Detroit-Ann Arbor-Flint CMSA	78%	22%	73%	27%
Indianapolis MSA	85%	15%	82%	18%
Milwaukee-Racine CMSA	84%	16%	78%	12%
Philadelphia-Wilmington-Atlantic City CMSA	79%	21%	73%	27%
Richmond-Petersburg MSA	68%	32%	65%	35%
Chicago-Gary-Kenosha CMSA	80%	20%	67%	33%
LA CMSA	90%	10%	55%	45%

The income assigned to each racial group is representative of the median household income reported in the 2000 Census. Median household income is $44,687 and $29,423 for the white only and black only populations; respectively.

It is assumed that both races prefer living with their own race. This preference is captured by the bliss point (D) of 0.8. While in reality racial preferences are likely to differ across race, setting the bliss points equal facilitates the evaluation of the effect of racial preferences.[12]

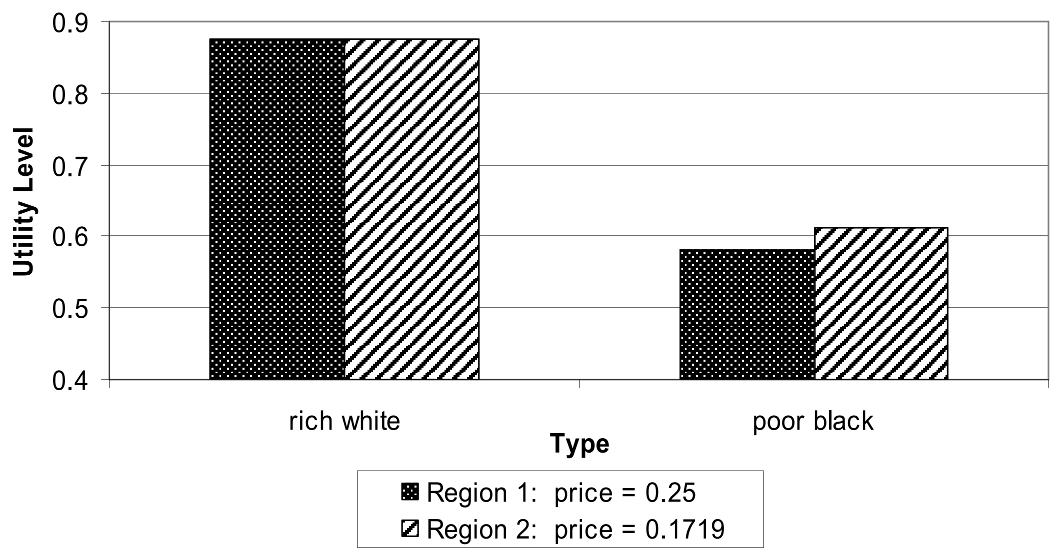
Recall that land stock will be assumed to be the same across regions. In addition, the total land stock must be equal to the population size since land consumption is fixed and assuming lot size is normalized to 1. Baseline values for environmental quality were selected to provide a significant difference between the two regions. Thus, the environmental quality is assumed to be twice as "good" in $j1$ as $j2$. Finally, since housing expenditures have been estimated to represent approximately 30% of total expenditures,

[12] The survey literature related to racial preferences provides the most reasonable guidance for the selection of values for the bliss points. However, the results from these surveys are not perfectly tractable to this parameter. In general, the literature concludes that whites have "stronger" racial preference (see, for example, Farley 1994 and 1997). To capture this heterogeneity in racial preferences, a possible calibration for the racial bliss point would be 0.9 and 0.5 for whites and blacks; respectively. These bliss points were tested within the model, and the results were qualitatively the similar to the specification used in the paper.

α and β will be assigned values of 0.7 and 0.3, respectively.[13] Lastly, the price in $j1$ is fixed at $p_1 = 0.25$ in order to identify a unique price in $j2$.

First, consider the model with no racial preferences ($\eta = 0$). Since the wealthy white population will be residing in both regions, prices are such that this population is indifferent in equilibrium.[14] Figure 1 reports the achievable utility levels across regions for each group when $\gamma = 0.1$.

FIGURE 1: Utiltiy Level in Equilibrium - No Racial Preferences

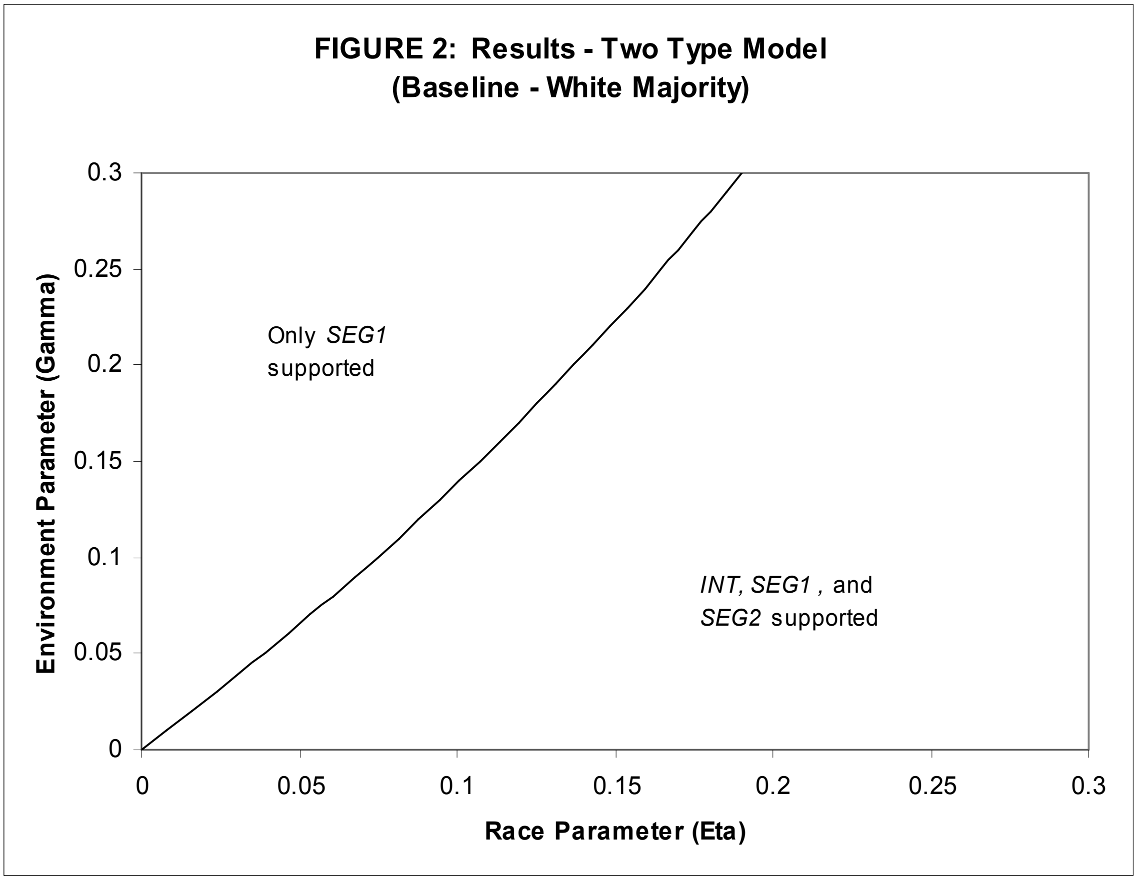


Consistent with the analytical discussion, the only equilibrium that will be supportable is equilibrium *SEG1*. Recall, this equilibrium reflects a distribution in which the rich white population occupies the high environmental quality region, while in the low environmental quality region the entire poor black population lives with the remaining indifferent whites. This result holds as γ varies.

[13] With fixed land consumption this relationship typically does not hold. However, using this parameter specification is a reasonable starting point.

[14] No further assumption regarding the composition of each region needs to be made since utility is independent of the racial composition.

The analysis of Section III showed that once racial preferences are introduced, three different equilibria may be supportable. Figure 2 shows which equilibria are supportable as a function of γ and η.



As expected, the partial segregation distribution with the poor black population living in the low environmental quality region (*SEG1*) is still supported and robust following the introduction of racial preferences. With the assumed population distribution, both the white and black populations perceive racial quality to be more favorable in $j2$. As predicted, for the black population the gap is significant with the perceived racial quality being more then twice as favorable in $j2$ ($R_{b1} = 0.36$ vs.

$R_{b2} = 0.75$). Alternatively, for the white population the gap is minimal ($R_{w1} = 0.96$ vs. $R_{w2} = 0.99$).

Nevertheless, with the small perceived change in quality for the white population, the indifference price increases slightly in $j2$ (for every parameter combination) once racial preferences are introduced.[15] Furthermore, there is a small parameter space where the white population's ranking of the regions reverses; thus, the indifference price in $j2$ is slightly more than 0.25.[16] However, even in this range, the black population remains better off in the low environmental quality region.

Now consider the partial segregated equilibrium with the poor black population living in the high environmental quality region (*SEG2*). As shown in Figure 2, for a subset of the parameter space this distribution can be supported in equilibrium once racial preferences are introduced. The line in Figure 2 represents the threshold above which the equilibrium is no longer supported. The indifference price for the white population will now reflect the higher environmental quality and more favorable racial quality in $j1$. Therefore, in comparison to the model without racial preferences, the indifference price decreases slightly in $j2$ (for every parameter combination).[17] The equilibrium is supported when the racial quality gap adequately compensates the black population for the higher relative price in $j1$. Above the threshold, environmental tastes dominate and the high perceived racial quality is no longer significant enough keep the black population in the high environmental quality region.

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[15] For example, with $\gamma = 0.1$ the price in $j2$ equals 0.1723, 0.1756, and 0.1828 for $\eta = 0.01$, 0.1, and 0.3; respectively.

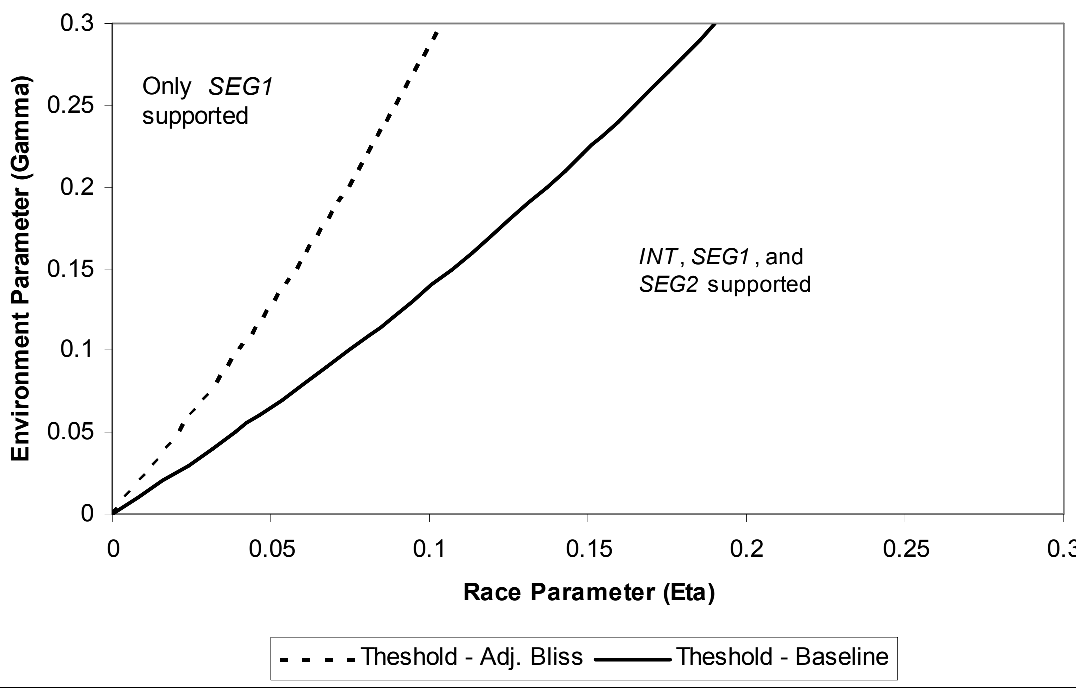
[16] The reversal arises when the relative magnitude between racial preferences and environmental preferences strongly favors race. For instance, for $\eta = 0.1$, the white population favors the overall quality in $j2$ if $\gamma < 0.0044$.

[17] For example, with $\gamma = 0.1$ the price in $j2$ equals 0.1715, 0.1682, and 0.1603 for $\eta = 0.01$, 0.1, and 0.3; respectively.

An integrated distribution (*INT*) can also be supported once racial preferences are introduced. In contrast to the above cases, the population distribution across regions is not predetermined. In equilibrium, the distribution as well as the price in *j*2 is recovered. Support for this distribution lies in almost the exact parameter space as *SEG2*. However, along the threshold, the integrated equilibrium is not supported whereas *SEG2* is supported. Recall that this equilibrium is highly unstable. Specifically, any change in the environmental quality or distribution would drive the distribution to one of the partial segregated equilibrium.

Finally, I consider the role of racial preferences by adjusting the racial bliss point from 0.8 to 0.9 (Figure 3).[18]

FIGURE 3: Results - Two Type Model
(Adjusted Racial Bliss Point - White Majority)



[18] This result could also be reached by assuming a different population distribution. One example would be an assumed population distribution with 1.3 and 0.7 proportions for the white and black populations; respectively. This distribution would result in the following perceived racial quality for *SEG2*: $R_{w1} = 0.75$ vs. $R_{w2} = 0.96$ and $R_{b1} = 0.99$ vs. $R_{b2} = 0.36$.

Observe that the parameter space where *SEG2* and *INT2* are supported increases significantly under the adjusted specification.[19] Consider the impact on *SEG2* – the black population residing entirely in the high environmental quality region (*j*1). Under this population distribution, the white population now perceives *j*2 to have more favorable racial quality ($R_{w1} = 0.96$ vs. $R_{w2} = 0.99$). The black population continues to favor j1 ($R_{b1} = 0.64$ vs. $R_{b2} = 0.19$). For the black population the racial quality gap has increased. Furthermore, the relative gap between races increases from the previous specification. Consequently, the role of perceived racial quality is more significant in supporting the equilibrium.

Working though the parameterized model demonstrates the results predicted in the analytical analysis. With this approach in mind and the intuition gained from the two type model, I will now expand the model to include all four types. The evaluation of the full model allows for heterogeneity of income within each race. This generalization makes it possible to separate income and racial effects on locational choice.

The specification with all four types is evaluated using a similar approach to that laid out above. The population distribution was constructed using data from the 2000 US Census. I define rich households as households earning at least the median income. Using this approach, approximately 55% of the white population and 37% of the black population are categorically defined as rich households.[20] Holding the proportion of black households at 15% as in the two type model, the following table describes the assumed population distribution across the four types:

[19] While not reflected in the figure, support for *SEG1* also becomes more robust.

[20] The median household income in the US was reported to be $41,994. For income distributions within race, the nearest break provided by the Census is $40,000. Therefore, I use this break as the estimated median income.

TABLE 4: Assumed Exogenous Variable Values (Four Types)				
Exogenous Variables	Type			
	w_H	w_L	b_H	b_L
pop. (N_i)	0.95	0.75	0.1	0.2
income (y_i)	1	0.67	1	0.67
bliss (D_r)	0.8	0.8	0.8	0.8

Observe that the total white population exceeds the total black population and the total rich population exceeds the total poor population.[21] Thus, both white and rich individuals will reside in both regions. The remaining parameters are consistent with the two type model (as reported in Table 2). Recall that the environmental quality is assumed to be more favorable in $j1$.

In contrast to the two type model, by considering four types there are many racial distributions across regions that are possible in equilibrium. However, using the assumed population distribution reduces the set of distributions that are possible. For example, it is not possible to have the rich white population living entirely within a region with the entire population of any other type. For tractability, only distributions that have one type split across regions will be explicitly considered. Several distributions in which two types lived across regions were tested and none were supported in equilibrium. Table 6 lists the considered potential equilibria:

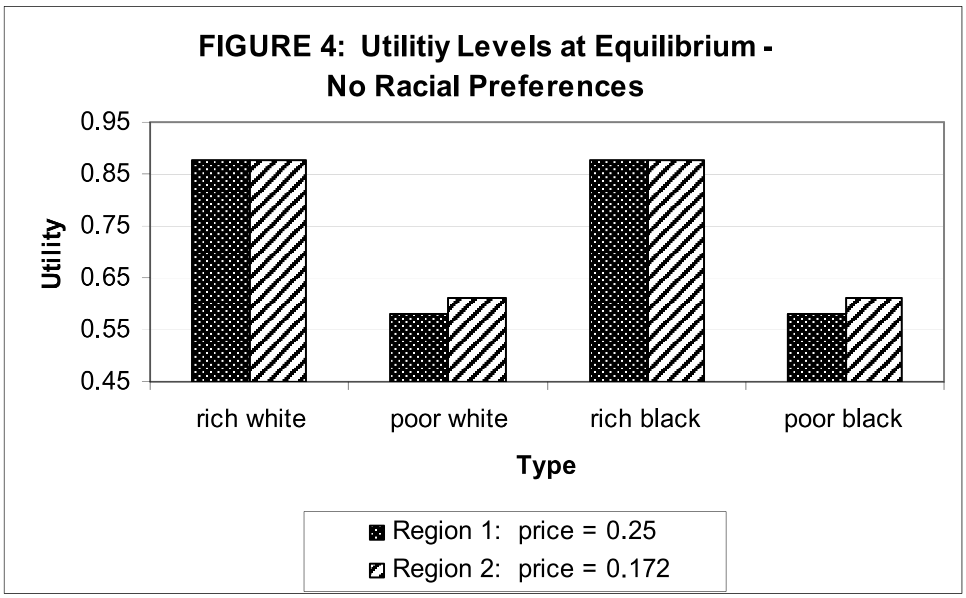
[21] While the assumed distribution of types impacts equilibrium results (e.g., prices), the fundamental conclusions are unaffected.

TABLE 5: Potential Equilibria (Four Types)			
	Location of Types		
Case	Both	$j1$	$j2$
Stratification by Race – Black pop. in region 2 (RB2)			
RB2.WH	w_H	w_L	b_H, b_L
RB2.WL	w_L	w_H	b_H, b_L
Stratification by Race – Black pop. in region 1 (RB1)			
RB1.WH	w_H	b_H, b_L	w_L
RB1.WL	w_L	b_H, b_L	w_H
Stratification by Income – Poor pop. in region 2 (IP2)			
IP2.WH	w_H	b_H	w_L, b_L
IP2.BH	b_H	w_H	w_L, b_L
Stratification by Income – Poor pop. in region 1 (IP1)			
IP1.WH	w_H	w_L, b_L	b_H
IP1.BH	b_H	w_L, b_L	w_H
Other			
O.1	w_H	w_L, b_H	b_L
O.2	w_H	b_L	w_L, b_H
O.3	b_L	w_H	w_L, b_H
O.4	b_L	w_L, b_H	w_H

When possible, the potential equilibria are grouped to include cases which reflect the same distributions across either race or income. For instance, RB2.WH (Stratification by **R**ace – **B**lack Population in Region **2** – **R**ich **W**hite Population in Both Regions) and RB2.WL are equilibria that reflect the same racial distribution. The only difference is the specific distribution of the rich white and poor white populations. The "Other" grouping represents equilibria in which rich and poor as well as black and white live across regions.

As with the two type model, the above cases hinge on condition *EQ1*. For instance, in order to support equilibrium RB2.WL the following must hold: (1) the rich white population is at least as well off in $j1$, (2) the rich black and poor black populations are at least as well of in *j*2, and (3) the poor white population is indifferent between regions.

To provide a point of comparison, it is worth quickly discussing the model in the absence of racial preferences. Under these preferences, the model collapses to the two type model because race doesn't affect an individual's decision. Therefore, the only supportable equilibria are ones in which the total poor populations (both white and black) are living in the low environmental quality region. Figure 4 depicts this result by comparing achievable utility for each type across regions:



Prices reflect indifference for the rich population. Thus, within the set of equilibria listed in Table 5, only the two equilibria that reflect stratification of income with the poor population in *j*2 (IP2.WH and IP2.WL) could be supported. Again, with this result in mind, the impact of introducing racial preferences will be investigated.

Of the twelve potential equilibria, four are supportable once racial preferences are introduced. Table 6 summarizes the results:

TABLE 6: Results (Four Types)					
	Location of Types				
Case	Both	$j1$	$j2$	Supportable	Reason Unsupportable
Stratification by Race – Black pop. in region 2 (RB2)					
RB2.WH	w_H	w_L	b_H, b_L	Yes	--
RB2.WL	w_L	w_H	b_H, b_L	Yes	--
Stratification by Race – Black pop. in region 1 (RB1)					
RB1.WH	w_H	b_H, b_L	w_L	Yes	--
RB1.WL	w_L	b_H, b_L	w_H	No	$V_{w_H 1} \geq V_{w_H 2}$
Stratification by Income – Poor pop. in region 2 (IP2)					
IP2.WH	w_H	b_H	w_L, b_L	No	$V_{b_H 1} \leq V_{b_H 2}$
IP2.BH	b_H	w_H	w_L, b_L	Yes	--
Stratification by Income – Poor pop. in region 1 (IP1)					
IP1.WH	w_H	w_L, b_L	b_H	No	$V_{w_L 1} \leq V_{w_L 2}$ and $V_{b_H 1} \geq V_{b_H 2}$
IP1.BH	b_H	w_L, b_L	w_H	No	$V_{w_L 1} \leq V_{w_L 2}$ and $V_{b_L 1} \leq V_{b_L 2}$
Other					
O.9	w_H	w_L, b_H	b_L	No	$V_{w_L 1} \leq V_{w_L 2}$ and $V_{b_H 1} \leq V_{b_H 2}$
O.10	w_H	b_L	w_L, b_H	No	$V_{b_H 1} \geq V_{b_H 2}$
O.11	b_L	w_H	w_L, b_H	No	$V_{w_L 1} \geq V_{w_L 2}$
O.12	b_L	w_L, b_H	w_H	No	$V_{w_H 1} \geq V_{w_H 2}$

For the eight equilibria that are not supported, at the indifference prices, at least one type can be made better off by moving to the other region. Consider, for example, case IP2.WH, an equilibrium that is supported in the absence of racial preferences. Observe that the perceived racial quality is known since the racial distribution is fixed.[22] For this parameter specification, both the white and black populations prefer the perceived racial quality in $j2$. However, the racial quality gap for the white population is small ($R_{w1} = 0.99$ vs. $R_{w2} = 1$) compared to the gap perceived by the black population ($R_{b1} = 0.51$ vs. $R_{b2} = 0.64$).

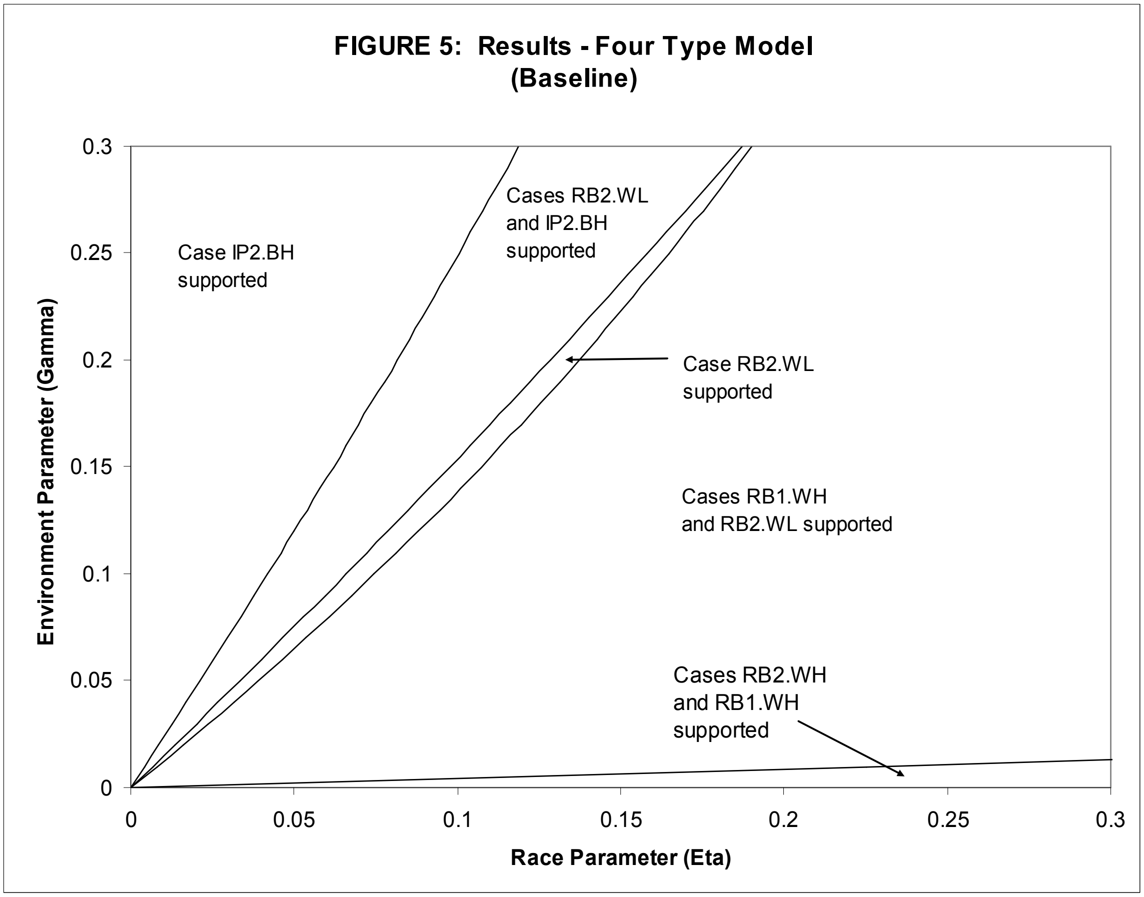
[22] This observation is true for all the equilibria cases laid out in Table 6.

This case requires that prices adjust to make the rich white population indifferent between regions. At these prices, from condition *EQ1*, this equilibrium is supported if: (1) the poor white and poor black populations are at least as well off in $j2$ and (2) the rich black population is at least as well off in $j1$.[23] However, over the entire parameter space, the rich black population can always be made better of by moving to $j2$. Therefore, this equilibrium, which assumes the rich black population residing in $j1$, is not supportable.

Intuitively, for the distribution assumed in this potential equilibrium, the rich white population will always perceive $j1$ to be more favorably than the rich black population. With the same income, the rich white and rich black populations have the same marginal willingness to pay for overall quality. Therefore, at the indifference prices for the rich white population, the rich black population will always prefer to live in $j2$. The general intuition behind the supportability of this equilibrium can be followed to understand the outcomes of all the equilibria – whether supportable or not.

The remainder of this section focuses on the four equilibria (Cases RB2.WH, RB2.WL, RB1.WH and IP2.BH) which can be supported. Figure 5 below depicts when these equilibria can be supported as a function of γ and η.

[23] For all the cases considered, conditions *EQ2* and *EQ3* will be satisfied in equilibrium since the population distribution is fixed.



In general, this figure demonstrates how the set of supportable equilibria are dependent on the relative tastes for environment and race. The bottom right of the figure represents strong racial preferences relative to environmental preferences. This relationship switches moving toward the top left corner of the parameter space. Observe, when racial preferences are dominant, the equilibria that reflect stratification by race are supported (RB1 and RB2). As environmental tastes gain importance these equilibria lose support while stratification by income (IP2.WL) becomes supportable and remains supported through the remainder of the parameter space considered.

Exploring this sensitivity analysis in greater detail provides additional insights into the behavior of the model and its predicted outcomes. Consider the relationship between RB2.WH and RB2.WL. As demonstrated in the two type model, with the assumed population distribution across race and as a consequence of the functional form of perceived racial quality, the white and black populations perceived the racial quality to be favorable for the same region – $j2$. Except for a small portion of the parameter space, the white population perceives the *overall* quality to be more favorable in $j1$. Only when racial preferences significantly dominate is the overall quality in $j2$ favored. Since the rich white population has a higher marginal willingness to pay for overall quality (compared to the poor white population), they will always be willing to pay more for the higher quality regions. This observation explains the link between RB2.WH and RB2.WL. Specifically, RB2.WL is supported when the overall quality in $j1$ is favored and opposite is true for RB2.WH. Since these equilibria reflect the same racial distribution, I will often refer to these cases jointly as RB2. Whether the price reflects indifference for the rich or poor white population, the entire black population is content in the low environmental quality region ($j2$) for a considerable portion of the parameter space. RB2.WL becomes unsupportable when environmental preferences reach a level of relative importance in which the rich black population would be better off living in the $j1$ – the high environment quality region. Prior to this threshold, the rich black population is willing to forgo the high level of environmental quality in $j1$ for the significantly higher level of racial quality perceived in $j2$.

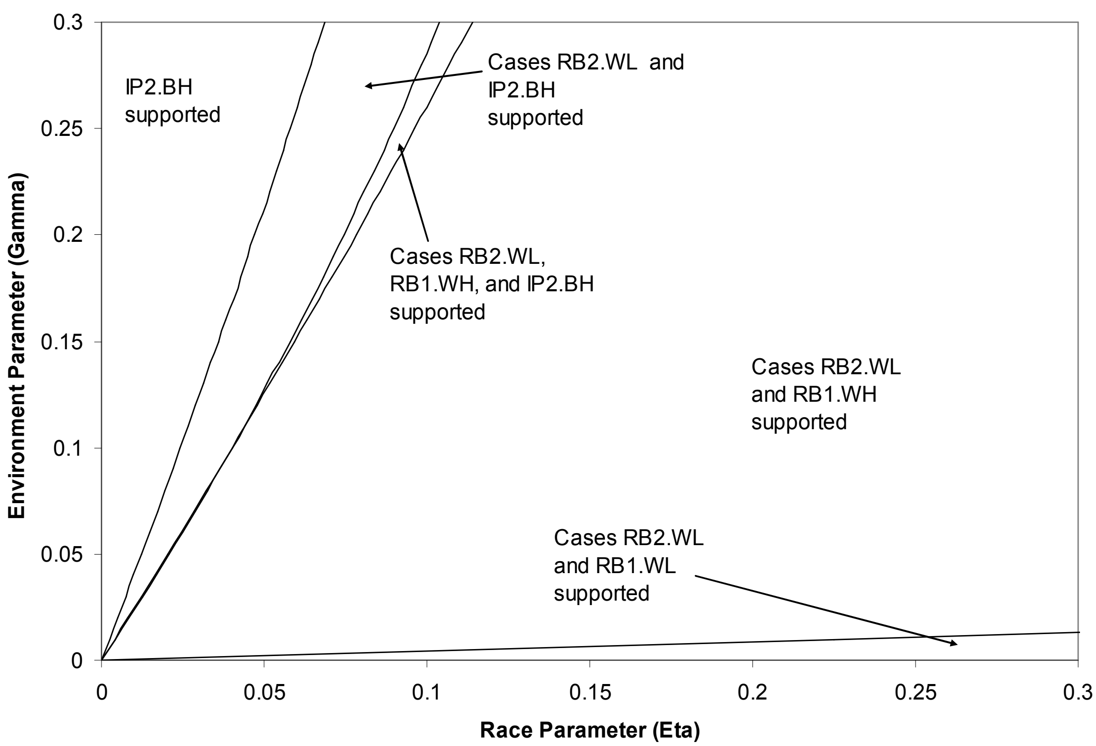
Support for RB1.WH is less robust than RB2. As taste for environmental quality increases in importance, the relative price in $j1$ also increases for the rich white population to remain indifferent. As depict in the figure, there exists a threshold where the relative strength of environmental preferences leads to a significantly high indifference price such that the poor black population would prefer *j*2 – even though the region has significantly lower racial and environmental quality.

In terms of environmental justice the results above are quite significant. When supportable, RB2 reflects a distribution that would traditionally be labeled as environmental injustice. Specifically, even when controlling for income, the black population is disproportionately exposed to low environmental quality. Alternatively, support for RB1.WH indicates that is also possible to observe a distribution in which the white population bears a disproportion burden of low environmental quality. Support for both these distributions may reflect the importance of initial racial compositions – prior to changes in environmental quality. Nevertheless, it is important to recognize that these equilibria are supported independent of the siting of environmental hazards and independent of any form of direct discrimination. Support comes simply by the introduction of racial preferences.

Lastly, consider IP2.WL – an equilibrium that is supported in the absence of racial preferences. This equilibrium is only supportable when environmental preferences are strong relative to racial preferences – an intuitive result. It is worth noting that this distribution would also be interpreted as reflecting environmental injustice. The result is significant in demonstrating that sorting by income is still a possible outcome even in the presence of racial preferences.

Next, I explore how a change in perceived racial quality affects the outcomes. The specification is adjusted to represent the case in which the two races perceive the racial quality to be more favorable in different regions. As with the two type model, this result is accomplished by increasing the racial bliss point from 0.8 to 0.9. Figure 6 below depicts how the expected outcomes of the model are altered under this adjusted specification.

FIGURE 6: Results - Four Type Model (Adjusted Bliss Point)



There are several implications of moving the bliss point towards increased segregation. First, RB2.WH is no longer a supportable equilibrium. With the entire black population in *j*2, the white population perceives the overall quality (and racial quality) in *j*1 to be more favorable *over the entire parameter space*. Therefore, RB2.WL is the only possible distribution that can be supportable under this racial distribution. However, now when the entire black population resides in *j*1, the white population perceives the racial quality to be more favorable in *j*2. Therefore, for a small portion of the parameter space the white population perceives the overall quality in *j*2 to be more favorable. This result gives rise to the support of RB1.WL. Thus, under this specification, RB1.WH and RB1.WL are linked and represent the same racial distribution - referred jointly as RB1.

Also, observe that the parameter space in which RB2 and RB1 are supportable increases under this specification. Alternatively, the parameter space for IP2.BH decreases. As in the two type model, the relative racial quality gap between races increases considerably from the previous specification. Consequently, the impact of racial preferences increases.

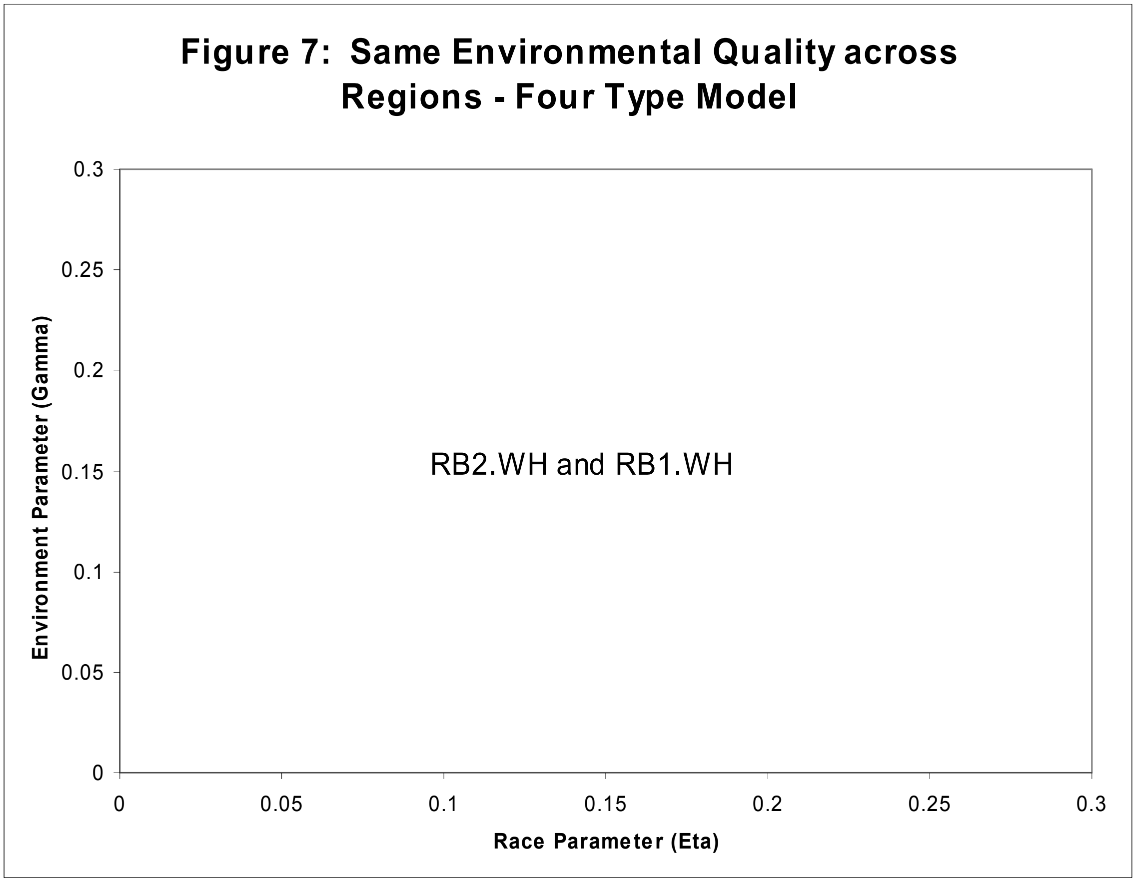
V. *Impacts from Changes to Environmental Quality*

In this section two scenarios will be investigated:

1. Suppose each region initially has the same level of environmental quality. What is the impact of introducing an environmental hazard to region 2?
2. Given the differential in environmental quality investigated in the previous section (environmental quality in region 1 (g_1) = 2 vs. environmental quality in region 2 (g_2) = 1), what is the impact of an improvement to low environmental quality region ($g_2 = 1 \rightarrow g_2^{'} = 1.5$)?

I begin with scenario (1). Before considering the impact of the introduction, it is necessary to determine what equilibria are supportable in the initial state. The parameterization remains the same as the baseline full model with the exception of environmental quality ($g_1 = g_2 = 2$). With overall quality only differentiated by perceived racial quality, only equilibria with stratification by race are supportable. Specifically, only RB2.WH and RB1.WH are supportable (Figure 7).[24] Furthermore, these equilibria are supported over the entire parameter space. This result parallels the outcome of the model without racial preferences in which only distributions reflecting stratification by *income* were supportable.

[24] Under the adjusted specification (racial bliss point increased from 0.8 to 0.9), RB2.WL and RB1.WL are the supported equilibrium.



Following the introduction of an environmental hazard, the model returns to the specification discussed in the previous section (g_1 = 2 vs. g_2 = 1). Recall the summary of results provided in Figure 5. As posited in Section 4, the initial distribution of households plays an important role in understanding observed distribution when the economy returns to equilibrium. However, once the environmental hazard is introduced, the stability of the initial distribution depends on relative preference for environment and race.

Suppose the initial equilibrium is RB2. Following the introduction, this racial distribution remains a stable equilibrium if relative preferences fall within the supportable portion of the parameter space (i.e., to the right of the threshold for RB2.WL). However, if households' relative preferences exist to the left of the threshold, the equilibrium will become unsupportable. Specifically, compared to the poor white population, the rich black population will have a higher willingness to pay to live in $j1$. Consequently, equilibrium forces will drive the distribution to IP2.BH.

Assuming RB1 as the initial distribution leads to several interesting possible outcomes following the introduction of an environmental hazard. First, if household preferences exist within the portion of the parameter space where RB1 is supportable, the equilibrium will remain stable.

To the left of the threshold, the equilibrium becomes unstable. Under this scenario, the path to a new equilibrium is somewhat complex. At the prices in which the rich white population is indifferent, the poor black population is better off living in $j2$. As a result, forces will drive the entire poor black population to migrate to the low environmental quality region by purchasing housing stock from the rich white population. However, this shift in population tips the racial quality perceived by the black population in favor of $j2$. Ultimately, with the change in quality, at indifferent prices for the rich white population, the rich black population also favors $j2$. Thus, the rich black population will replace the remaining rich white population in $j2$.

At all parameter combinations left of the threshold, forces will drive the distribution to at least this point. However, as depicted in Figure 5, RB2.WL and IP2.BH are possible outcomes in equilibrium. Suppose, preferences fall within the small portion where only RB2.WL is supportable. Here the rich black population will continue moving into $j2$ by consuming housing stock from the poor white population until the entire rich black population resides in $j2$. Ultimately, the poor white population will live in both regions and prices will reflect indifference for this population. At these prices, all types will be content with the population distribution (RB2.WL) and the economy will be back in equilibrium.

A different outcome will arise if preferences fall into the portion where only IP2.BH can be supported. In this case, the rich black population will not be willing to pay a price that the poor white population would accept to move. Therefore, no further changes in the distribution will be observed. However, prices will adjust such that the rich black population is indifferent – equilibrium IP2.BH.

Finally, preferences may lie in a portion of the parameter space in which either RB2.WL or IP2.BH can be supported in equilibrium. The final distribution will depend on whether the rich black population or the poor white population is relatively better off in *j*2. Specifically, after consuming all the rich white population's housing stock in *j*2, the rich black population will attempt to purchase stock from the poor white population. If a transaction price is found then the equilibrium will be RB2.WL; otherwise, IP2.BH will be supported in equilibrium.

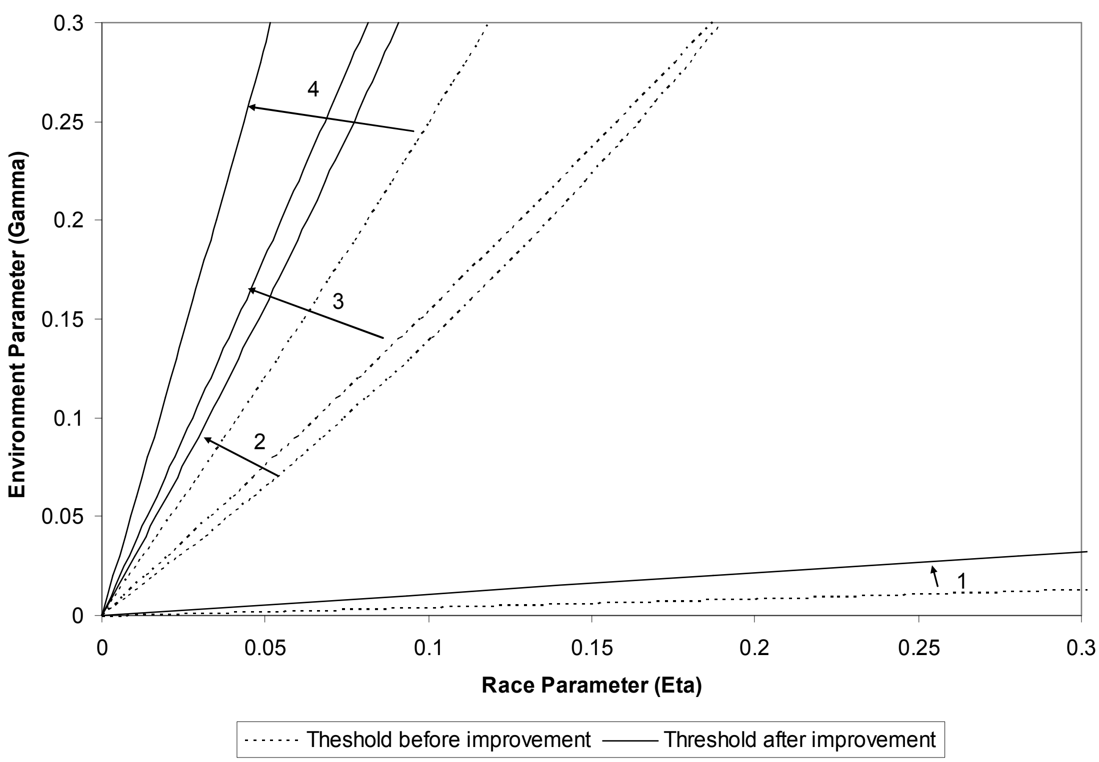
This application of the model demonstrates both the importance of the initial population distribution as well as the relevance of relative preference for environment and race. Furthermore, it provides intuitive predictions following the introduction of environmental hazards.

Now consider scenario (2): an improvement in the environmental quality in the low environmental quality region (*j*2) from $g_2 = 1$ to $g_2^{'} = 1.5$.

First, observe that without racial preferences the model will remain stable as long as the improvement is not beyond that of the high environmental quality region. Recall that the only equilibria that are supportable are ones in which the poor live in the low environmental quality region.

Consider the impact of the improvement on the model with racial preference. Figure 7 below depicts the changes to the baseline model:

FIGURE 7: Improvement in Environmental Quality in *j* 2
(increase in *g* from 1.0 to 1.5)



The dashed and solid lines represent the thresholds before and after the improvement; respectively. The arrows represent the change in the threshold for each equilibrium: (1) RB2.WH, (2) RB1.WH, (3) IP2.BH, and (4) RB2.WL.

The consequence of the improvement is straightforward. Basically, the importance of racial quality increases relative to environmental quality as a result of the environmental quality gap shrinking. Therefore, if the economy was in equilibrium under either RB2 or RB1, the racial distribution in equilibrium would remain stable. In other words, equilibria which reflect stratification by race would continue to be supportable following the improvement.

Alternatively, if the economy reflected IP2.BH prior to the improvement, it is possible that this equilibrium would become unsupportable. Furthermore, the most likely result would be a shift to RB2. Specifically, at the indifference price for the rich black population, the poor white population would be better of living in $j1$. Consequently, the poor white population will migrate to $j1$ by consuming housing stock from the rich black population. Equilibrium will be reached when the distribution reflects RB2 and prices reflect indifference for the poor white population.

Even parameter combinations in which either RB1 or RB2 could be supported; the rich white population will always be willing to pay more than the poor white population to live in $j1$. Therefore, the economy will still be driven to RB2.

Working through this scenario also demonstrates interesting insight into the possible behavior of households in this setting. As environmental quality is more evenly distributed across neighborhoods, the more likely the economy will reflect a population distribution which is stratified by race. Furthermore, improvements are more likely to drive migration towards equilibria that reflect environmental injustice (RB2).

VI. Conclusion

Understanding issues associated with the notion of environmental justice requires an understanding of siting practices as well as the migration patterns following and resulting from the siting of hazards. This paper has highlighted and motivated the importance of the latter. Using a simple model with both environmental and racial preferences, it has been shown that self-segregating behavior can contribute to households sorting in such a way that may be perceived as environmental injustice.

These results also demonstrate the potential significance of population proportions, neighborhood size, and number of neighborhoods within a household's locational choice set. For example, it may be possible that no matter how the population sorts across regions, the perceived racial quality may never be too "unfavorable" for the majority population. If the majority racial group prefers living with their own race, then the more the economy is dominated by that race, the more likely individuals of that race can find a region with both favorable perceived racial quality and environmental quality. Conversely, minority groups may be faced with constrained choices such that the regions offer either high perceived racial quality or high environmental quality. This constraint may ultimately lead minority households to choose neighborhoods with high perceived racial quality over neighborhoods with high environmental quality.

Furthermore, the potential for multiple equilibrium suggests that the initial distribution of households (at the time of siting) may be a critical factor in explaining the currently observed distribution. This observation was investigated in the previous section and clearly demonstrated the importance of the initial distribution. The findings from this application also demonstrated the tendency for stable equilibria to move toward what would typically be view as environmental injustice.

These conclusions have important implications for both policy and research. This simple model, under relatively strong assumptions, has demonstrated the potentially confounding affect racial preferences may have on the distribution of households around environmental quality. There is substantial evidence in the literature suggesting that these preferences do exist. Thus, not accounting for preference for racial composition may lead to incorrect or inaccurate inferences in empirical research. An ultimate consequence would be ineffective policies. These implications have not been thoroughly investigated in an environmental justice context.

It is important to note that this final remark is not only true for environmental justice, but can also be generalized to other local public goods (i.e., school quality, level of crime, etc.). Specifically, the observed consumption of local public goods across racial groups may be misinterpreted if racial preferences are not accounted.

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