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Can Socioeconomic Status Substitute for Race in Affirmative Action College Admissions Policies? Evidence from a Simulation Model

AUTHORS

Sean F. Reardon
Stanford University

Rachel Baker
University of California, Irvine

Matt Kasman
Brookings Institution

Daniel Klasik
George Washington University

Joseph Townsend
Stanford University

ABSTRACT

This paper simulates a system of socioeconomic status (SES)–based affirmative action in college admissions and examines the extent to which it can produce racial diversity in selective colleges. Using simulation models, we investigate the potential relative effects of race- and/or SES-based affirmative action policies on the racial and socioeconomic distribution of students in colleges. These simulations suggest four important patterns: (a) even relatively aggressive SES-based affirmative action policies do not mimic the effects of race-based policies on racial diversity; likewise race-based affirmative action policies do not mimic the effects of SES-based policies on SES diversity; (b) SES-based affirmative action in combination with targeted recruitment shows the potential to be comparable to race-based affirmative action on its own; (c) there is little evidence that, for minority students, race-based policies lead to differences in the average achievement of their college peers that are notably greater than the differences we observe under SES-based affirmative action or scenarios with no affirmative action of any type; and (d) the use of affirmative action policies by some colleges reduces the diversity of similar-quality colleges that do not have such policies.

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Can Socioeconomic Status Substitute for Race in Affirmative Action College Admissions Policies? Evidence from a Simulation Model

Sean F. Reardon*

Rachel Baker**

Matt Kasman+

Daniel Klasik++

Joseph B. Townsend*

*Stanford Graduate School of Education

** University of California, Irvine - School of Education

+ Brookings Institution

++ George Washington University

Corresponding author: Sean F. Reardon, e-mail: sean.reardon@stanford.edu.

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Abstract

This paper simulates a system of socioeconomic status (SES)–based affirmative action in college admissions and examines the extent to which it can produce racial diversity in selective colleges. Using simulation models, we investigate the potential relative effects of race- and/or SES-based affirmative action policies on the racial and socioeconomic distribution of students in colleges. These simulations suggest four important patterns: (a) even relatively aggressive SES-based affirmative action policies do not mimic the effects of race-based policies on racial diversity; likewise race-based affirmative action policies do not mimic the effects of SES-based policies on SES diversity; (b) SES-based affirmative action in combination with targeted recruitment shows the potential to be comparable to race-based affirmative action on its own; (c) there is little evidence that, for minority students, race-based policies lead to differences in the average achievement of their college peers that are notably greater than the differences we observe under SES-based affirmative action or scenarios with no affirmative action of any type; and (d) the use of affirmative action policies by some colleges reduces the diversity of similar-quality colleges that do not have such policies.

Can Socioeconomic Status Substitute for Race in Affirmative Action College Admissions Policies? Evidence from a Simulation Model

In its 2013 *Fisher v. University of Texas at Austin* decision, the Supreme Court upheld the concept of affirmative action but issued a challenge to university administrators and scholars: In order to use race-based affirmative action, they must show "that no workable race-neutral alternatives would produce the educational benefits of diversity" (*Fisher v. University of Texas at Austin*, 2013, p. 11). The decision acknowledged that racial diversity is a legitimate goal of public university admissions policies, but the court expressed skepticism about whether race-based affirmative action policies were necessary to achieve that goal. After remanding the case to a lower court, the Supreme Court reheard the *Fisher* case during its 2015–16 term. Both the 2013 *Fisher* decision and its pending review by the court suggest that it is crucial that we understand the relative effectiveness of different types of admissions policies to increase racial diversity in selective colleges.

One potential workable race-neutral alternative admissions policy that might yield racial diversity at selective universities is affirmative action based on socioeconomic status (SES) rather than race. Such a policy would presumably avoid the constitutional challenge of racial discrimination. But can SES-based policies produce sufficient racial diversity to satisfy states' legitimate educational interests? This paper addresses that question.

This is, of course, a hypothetical question; few colleges currently use affirmative action based on SES in any substantial way. As a result, standard methods for evaluating existing policies cannot tell us how well they work. Moreover, college admissions and enrollment decisions at different universities are interdependent: Because students can apply to many colleges but enroll in only one, changes in admissions policies at one school may affect enrollment patterns at other schools. As a result, even if we knew the impacts of SES-based affirmative action in one university, those findings might not indicate what would happen if such policies were implemented in many universities. Given the hypothetical nature of SES-based affirmative action and the interdependent nature of the university admissions and enrollment processes, one very useful approach to understanding the potential impacts of different admissions policies is to use simulation models informed by the best available data. Well-designed simulations can allow rapid experimentation with a variety of policies and can provide insight into the probable composition effects of these policies on both individual universities and on the higher education system as a whole. Although simulations certainly are not definitive about what would actually happen under a given policy, they can describe patterns of probable outcomes under assumptions that are derived from other research and can provide guidance regarding the probably effectiveness of different types of policies.

With these aims in mind, this paper uses a simulation model to investigate the dynamic effects of various types of affirmative action college admission policies on campuses' racial and socioeconomic diversity, as well as resulting changes in the average academic achievement of students, both at schools that use these policies and those that do not. We also examine a common challenge to affirmative action: that students admitted under such plans are academically out-matched by their peers.

CURRENT PATTERNS OF RACIAL DIVERSITY AT SELECTIVE COLLEGES AND UNIVERSITIES

Any race-neutral affirmative action approach faces a difficult challenge. Even with the legality of race-conscious affirmative action policies, racial minority students remain underrepresented in higher education, particularly at selective institutions. Very selective colleges (those colleges with Barron's selectivity rankings of 1, 2, or 3[1]) have many more White, and many fewer Black and Hispanic, students

[1] Barron's Profiles of American Colleges (www.barronspac.com) provides selectivity rankings for most 4-year colleges in the United States. Colleges are ranked on a scale from 1 (*most selective*) to 6 (*least selective*). These rankings are based on the high school GPAs, high school class rank, and SAT/ACT scores of enrolled students, as well as the proportion of applicants admitted. Colleges ranked in the top two categories (1 and 2) in 2004 had median

than the U.S. population of 18-year-olds overall. This distribution is evident in Figure 1, which shows the postsecondary enrollment status of members of the high school class of 2004 by race and type of college or university. In this figure, the width of each bar represents the percentage of the college-age population enrolled in different types of colleges and universities (or not enrolled in any college, in the case of the leftmost bar); the vertical dimension describes the racial composition of students enrolled in each type of postsecondary institution. Appendix A includes a comparable figure describing the socioeconomic composition of postsecondary institutions.

[Figure 1 here]

In general, Black and Hispanic enrollment is lower in selective colleges and universities. The most highly selective colleges, however, are slightly more racially diverse than those just below them in the selectivity rankings. This difference may be partially the result of race-based affirmative action policies used by some of these most selective colleges. Although we do not know what the racial composition of these most selective colleges would be in the absence of any race-based affirmative action, their enrollments would likely consist of fewer than 10 percent Black and Hispanic students, much lower than the 30 percent Black and Hispanic individuals comprise in the overall population of 18-year-olds.

Existing research on the effects of affirmative action support these hypotheses. Evidence of affirmative action is most visible at selective, state-flagship universities (Backes, 2012; Brown & Hirschman, 2006; Hinrichs, 2012; Long, 2007). The elimination of affirmative action policies in some states has resulted in drops in the enrollment of Black and Hispanic students at these schools (Backes, 2012; Brown & Hirschman, 2006; Dickson, 2006; Hinrichs, 2012; Long, 2007). Some of this enrollment drop may be attributable to a decline in applications, perhaps because minority students interpret these bans as a signal that they are not welcome (Brown & Hirschman, 2006; Dickson, 2006).

SAT® scores of at least 575, admitted fewer than 50 percent of applicants, and enrolled students with median GPAs of about 3.5 and in the top 35 percent% of their high school class.

RACE-NEUTRAL AFFIRMATIVE ACTION POLICIES

State university systems have responded to bans on affirmative action either through increased recruitment of underrepresented students, through so-called “percent plans,” or both. The University of Washington, for example, was able to recover from a drop in applications from minority students with proactive recruitment of those students (Brown & Hirschman, 2006). California, in response to Proposition 209, saw less successful results from a similar strategy (Gándara, 2012). Recruitment efforts work in part by making colleges seem more appealing to prospective students through additional, targeted contact with those students. Texas took efforts to make its campuses seem more appealing to underrepresented students one step further and offered special scholarships for enrollment in the Texas flagship universities to students from high schools in low-income areas with a low college-going tradition (Niu & Tienda, 2010).

Often, targeted recruitment is paired with percent plan admissions policies. Under percent plans, any student who graduates in some pre-specified top percentage of their high school class automatically gains admission to the public university system. In order to increase the racial diversity of university admissions, such plans leverage the existing racial segregation of high schools; any plan that takes the top portion of a school with a high minority population is bound to admit a sizeable number of minority students. Percent plans have been implemented in the three largest states—California, Texas, and Florida. Evaluations of these policies indicate that they have not been effective at maintaining racial diversity levels in the event of a ban on affirmative action (e.g., Arcidiacono & Lovenheim, 2014; Bastedo & Jaquette, 2011; Horn & Flores, 2003; Lim, 2013; Long, 2004, 2007).

The failure of percent plans to deliver on their promise has, in part, prompted some scholars and colleges to propose an alternative race-neutral form of affirmative action, one that relies on SES instead of race to determine admissions preferences (Gaertner & Hart, 2013; Kahlenberg, 1996). Under SES-based affirmative action, students are given an admissions advantage because of their socioeconomic background rather than because of their race or ethnicity. The presumption is that such plans can effectively capitalize on the correlation between race and income in order to construct a racially diverse class of students. The potential effects of such policies are not clear. Some existing research suggests that substituting SES for race in college admissions decisions can at least partly maintain rates of minority enrollment while simultaneously increasing college access for economically disadvantaged students (Carnevale & Rose, 2004; Carnevale, Rose, & Strohl, 2014; Gaertner & Hart, 2013; Kahlenberg, 2012). Other research suggests that SES is not a sufficiently good proxy for race for SES-based policies to be effective at producing substantial racial diversity, at least without combining it with some form of race-awareness (Bowen, Kurzweil, & Tobin, 2005; Carnevale & Strohl, 2010; Espenshade & Radford, 2009; Kane, 1998; Long 2015; Reardon & Rhodes, 2011; Reardon, Yun, & Kurlaender, 2006; Xiang & Rubin, 2015). At the very least, SES-based affirmative action may help to increase socioeconomic diversity on college campuses, which in and of itself may be a desirable outcome for colleges. It is difficult to evaluate the effects of SES-based affirmative action in practice, however, because such plans are not widely used.

Our aim in this paper is to develop general intuition about SES-based affirmative action and the extent to which it can replicate, or even improve, the modest levels of racial diversity evident in selective colleges under current admissions practices. Specifically, we investigate the potential relative effects of race- and/or SES-based affirmative action policies on the racial and socioeconomic distribution of students into colleges.

In addition to this basic question of the potential for policy efficacy, we also investigate three other issues relevant to the assessment of affirmative action policies. First, in situations where colleges are not permitted to use race-based affirmative action, many turn to race-targeted recruitment. To understand how race-targeted recruitment might affect the racial and socioeconomic composition of colleges, we simulate the use of race-targeted recruitment in conjunction with SES-based affirmative action. This allows us to examine whether the combination of SES-based affirmative action and race-based recruiting can replicate or exceed the levels of racial diversity achieved through race-based affirmative action alone.

Second, some critics of race-based affirmative action claim that it does a disservice to racial minority students because it places them in environments where their academic preparation systematically falls below that of their peers (e.g., Arcidiacono, Aucejo, Coate, & Hotz, 2014; Arcidiacono & Lovenheim, 2005; Sander, 2004). This mismatch might lead to within-college racial segregation based on academic background or a lower likelihood that minority students admitted under affirmative action will complete college (Arcidiacono, Khan, & Vigdor, 2011). Other studies, however, indicate no significant negative effects of academic mismatch (Bowen & Bok, 1998; Dillon & Smith, 2015). In order to inform this line of research, we use our simulations to assess the extent to which race- and SES-based affirmative action policies might place minority students in colleges where their achievement falls substantially below that of their peers.

Third, we attend to the effects that affirmative action policies at one or more colleges have on enrollment patterns at other schools. College admission and enrollment processes take place in an interrelated, dynamic system where admissions policies at one college might affect enrollment patterns at other colleges. For example, application patterns changed in Texas after the introduction of the state's percent plan: non-flagship public universities in Texas saw an increase in the average test scores of their applicants, likely due to changes in application behavior of high-scoring students who were not eligible for automatic admission on the basis of their class rank (Long & Tienda 2010). Our aim is to expand such findings to examine how race- and SES-based affirmative action—arguably less-transparent than percent plans—might change application and enrollment patterns both at schools that use those policies *and* those that do not. The number of colleges using particular affirmative action policies may affect enrollment patterns throughout the system, and diversity gains in some colleges may be offset by diversity losses in others. Our simulations here provide insight into these potential system-wide, dynamic effects of affirmative action admissions policies.

THE UTILITY OF AGENT-BASED SIMULATION

We build intuition about the effects of different admissions policies using an agent-based model (ABM) that is grounded in real-world data and which incorporates a complex (though certainly highly stylized) set of features of the college application, admission, and enrollment processes. Our model is a synthetic world of students and colleges created to mimic the salient characteristics of students and colleges in the real world. These actors are given rules to engage independently in a process that simulates college admissions in the real world. By using an ABM, we are able to compare the effects of a range of policies on enrollment patterns in a way that takes into account how a policy would affect the full system of colleges. This model allows us to investigate how affirmative action policies might affect university composition in a world in which students (a) have idiosyncratic preferences about colleges, (b) have uncertainty about their own admissibility to each college, and (c) use their resources and limited information to strategically apply to a small subset of colleges, and in which colleges (a) differ in their use of affirmative action policies, (b) have idiosyncratic perceptions and preferences regarding students, and (c) strategically admit enough students to fill their seats under the expectation that not all students admitted will enroll. Although this model falls short of being completely realistic, it captures important dynamic features of the application/admissions/enrollment processes that enable us to investigate the ways that affirmative action might affect enrollments.

This simulation approach improves upon previous assessments of race and SES-based affirmative action in several important ways. First, unlike prior simulations, it models a dynamic system of students and colleges, rather than relying on static, regression-based or structural models. Nearly all previous studies of SES-based affirmative action have been based on simulations where regression-based estimates of race- or legacy-based admissions boosts are simply added to the academic qualifications of low income students from the original data to create a new hypothetical class of admitted students

(Bowen, Kurzweil, & Tobin, 2005; Carnevale & Strohl 2010; Espenshade & Radford, 2009).

Second, many of the studies that model application and admissions decisions have not directly addressed the potential of SES-based affirmative action, (Arcidiacono 2005; Howell 2010; Long 2015). Arcidiacono (2005) and Howell (2010) use structural models of the college enrollment process to examine the effect of changes in affirmative action policies on college enrollment choices (Howell, 2010) and future earnings (Arcidiacono, 2005). None of the simulations, however, include SES-based affirmative action. Alternatively, Long (2015) simulates changes in college diversity if colleges could give admissions boosts to students based on predictions of a student's race according to observable characteristics other than race, including measures of SES. Although these studies model application and admissions decisions explicitly, they too hinge on simply removing or adding various regression-estimated advantages to minority (or expected-minority) students in college admissions decisions.

Third, none of these approaches provide intuition on how application and admission behavior might change in *response* to the simulated outcomes of the changes in policy. This is not a trivial omission. We know, for example, UT Austin has had to add a cap to the number of students it admits under the Texas percent plan because demand for seats at the school is so high under the percent plan policy—a response that could not be modeled with structural approaches. Although we establish certain parameters of our model in similar ways to earlier models (such as estimating the size of the admission boost that might be appropriate to use for an SES-based affirmative action admissions policy), repeated simulations in our model allow both student and college behavior to change in response to different admission policies and the resulting changes in the size and composition of enrolling cohorts of students.

Fourth, previous simulation studies are also limited in the generalizability of their claims because of the data they use. For example, some are based on relatively small subsets of the postsecondary system ranging from a single state university (Gaertner & Hart 2013), to a single state system (Long 2015; Long & Tienda, 2010), to the 193 "most selective" colleges (Carnevale & Strohl 2010). This focus makes sense when the goal is to understand how admissions policies affect admission and enrollment patterns at particular types of schools, but it is not clear how far these results generalize to other institutions. Other simulations are based on more complete national data, but these data are usually old and likely unable to speak to more recent trends in college choice. For example, Howell (2010) uses data from the high school class of 1992, while Arcidiacono (2005) uses data from the class of 1972. Our simulated system includes 40 simulated institutions, but—along with the students in our simulation—they are constructed to represent the full system of degree-granting colleges and universities and the national population of high school students and is based on parameter estimates from 2004 and later.

Finally, our simulation approach is more realistic than other simulations in some important ways. For example, whereas the simulation in Carnevale and Strohl (2010) assumed that all students apply to all colleges, our model, like Howell (2010), has students strategically applying to a small portfolio of colleges based on their (imperfect) assessments of both college quality and their likelihood of admission. Moreover, in the Carnevale and Strohl (2010) simulation of SES-based affirmative action, the model measures socioeconomic disadvantage using many variables not typically available to admissions officers (for example, the percentage of individuals in an applicant's neighborhood who hold a college degree). Our model, in contrast, uses an index that is implicitly based on the types of factors (family income, parental education, parental occupation) that would be available to admissions officers.

SIMULATING THE MECHANICS OF AFFIRMATIVE ACTION POLICIES

Selective colleges generally try to admit classes of students that are both academically qualified and also diverse along numerous dimensions. These dimensions may include not only race or SES, but also academic interests, extracurricular talents, geography, and other factors. For example, colleges may want to boost enrollment in an undersubscribed major or program or find talented players for their sports teams. Selective colleges across the country demonstrate admissions preferences for these students who will add to the different types of diversity of their campus. These preferences—as well as racial or socioeconomic diversity preferences—are typically enacted through a holistic review process in which the overall academic achievement of an applicant is assessed across a host of dimensions.

Because it is part of a holistic process, the added weight given in the admissions process to students' nonacademic characteristics such as race is not explicit or directly measurable. Indeed, by law it cannot be: The Supreme Court has prohibited colleges from assigning numeric values to race-based characteristics (*Gratz v. Bollinger*, 2003). That is not to say, however, that the net average admissions weight given to a characteristic like race (or athletic prowess, for that matter) cannot be quantified after the fact given the right data. One can ask, for example, how much higher, on average, are the grade point averages (GPAs) of admitted White students than those of admitted Black students. The answers to questions of this type provide a way of quantifying the weight given to race and factors associated with race in a holistic admissions process. Thus, a nonzero answer to this question does not imply that admissions officers simply add a certain number of GPA points to each Black student's score and then admit all students simply on the basis of their (adjusted) GPA.

To make the simulations in this paper realistic, we simulate a holistic admissions process in which race and/or SES are given more or less (or no) weight in admissions decisions. For this, we need a sense of the average weight given to these factors by actual selective colleges and universities so that the simulations produce patterns that are grounded in real-world data.

Several existing papers have attempted to estimate the relative weight of race, SES, and academic record in admissions decisions at selective colleges. A common strategy is to use data from a pool of applicants to one or more selective colleges to predict admission on the basis of race, academic, and other observable factors and then compare the coefficients on the race variables with the coefficient on SAT® exam scores (see, for example, Kane (1998) and Espenshade & Radford (2009)). For example, if a Black student's probability of admission was 7 percent greater than an otherwise observationally identical White student, one can calculate what change in SAT® exam score would be needed to yield the same 7 percent boost in the probability of admission. We review these prior studies in some detail in Appendix B. Due to our concerns that the race weights estimated in these studies are likely too high, and because existing estimates do not describe the weight that colleges give to Hispanic students or to low-SES students, we also conduct our own simple analysis to estimate the relative weights given to race, SES, and academic performance in selective college admissions.

Using data from Educational Longitudinal Study of 2002 (ELS), we estimate racial and SES admissions weights using a much more parsimonious version of the model fit by Espenshade and Radford (2009) and Kane (1998). We predict the probability of admission using only test scores and dummy variables for race or a standardized variable for SES.[2] To account for the possibility that the implicit weights vary in magnitude along with the selectivity of the college, we repeated this analysis for admission to each of the six Barron's Selectivity categories.

The results of our analyses suggest that Black and Hispanic applicants to the most selective colleges receive an implicit admissions weight that is roughly equal to the weight given to a 1.3 standard deviation increase in academic performance (in other words, the difference in the probability of admission of White and Black or Hispanic students is roughly equal to the difference in the probability of admission of two students of the same race whose academic performance differs by 1.3 standard deviations). We find very little or no evidence of racial preferences in admissions to colleges in lower selectivity tiers (for details, see Appendix B, Table B1).

We find evidence of slight SES-based affirmative action in the most selective colleges—a standard deviation difference in family SES is roughly the same as a 0.15 standard deviation difference in academic

[2] In these analyses, we use SAT® scores because they are widely observable to colleges (unlike the tests administered as part of the ELS study) and they are standardized on a common scale (unlike GPA). Although colleges have access to other information about students, we use a single test score measure as a unidimensional proxy for students' academic performance. The weights we estimate therefore should be understood as designed solely to provide information about the rough order of magnitude of the weights given to academic performance, race, and SES in admissions processes. They are not particularly useful as estimates of actual admissions processes.

record. Moreover, students applying to less selective colleges appear to be penalized for their lower SES in the admission process. In these colleges higher SES students were given implicit preference in admissions decisions. The SES weights are, however, relatively small in all cases. This heterogeneity perhaps reflects the fact that existing SES-based admissions preferences work in two directions: On the one hand, most colleges rely heavily on student tuition and must take ability to pay into account in admissions; on the other hand, many colleges, particularly very selective colleges, actively recruit and admit low-SES students (for details, see Appendix B, Table B2).

This finding suggests that racial affirmative action plays (or played, in 2004) some role in admissions to highly selective colleges but SES-based affirmative action does not. We reiterate that our estimates are designed more to provide rough estimates of the average weight given to race in admissions processes than to precisely measure the impact of affirmative action policies. We use these estimates to determine the range of race and SES weights to use in the simulated affirmative action policies in our models.

METHOD

We use a modification of the agent-based model of college application, admission, and enrollment developed and described in depth by Reardon, Kasman, Klasik, and Baker (2016). The model includes two types of entities: students and colleges. We set up the model with 40 colleges and 10,000 new college-age students per simulated year. Students have three characteristics: race, a measure of high school academic achievement, and a measure of family resources. The race-specific distributions of academic achievement and resources, and race-specific correlations between resources and academic achievement were constructed based on the real-world relationships between these variables observed in ELS, a nationally representative sample of high school students who would graduate in 2004. The achievement distribution is based on the standardized assessments of English language arts and mathematics administered to that sample in 10th grade. The family resource dimension is based on a composite measure of a student's mother's and father's education, mother's and father's occupation, and family income generated by the National Center for Education Statistics. This measure captures the dimensions of class proposed by Kahlenberg (1996) for use in class-based affirmative action policies. The parameters used in our model are presented in Table 1.

For simplicity, as well as the availability of real-world data, we limited our model to the four largest racial groups in the United States: White, Hispanic, Black, and Asian. Five percent of the students in the simulation are Asian, 15 percent are Black, 20 percent are Hispanic, and 60 percent are White, roughly similar to actual proportions of the college-age population. The academic achievement characteristic represents the academic qualities that make a student attractive to a college (e.g., test scores, GPA, high school transcripts). We converted the scores from the original ELS test score scale to one that approximates the 1600-point SAT® exam scale (mean 1000, standard deviation 200) because of the ubiquity of this scale in general as well as its use in existing literature on affirmative action policies. The family resources measure is meant to represent the economic and social capital that a student can tap when engaging in the college application process (e.g., income, parental education, and knowledge of the college application process). The family resource measure is standardized to have a mean of 0 and standard deviation of 1.

Based on the findings of Reardon et al. (2016) and described more formally below, we structured the model to allow students' family resources to influence the college application process in four ways. First, students' resources and academic record are positively correlated. Second, students with more resources submit applications to more colleges than their lower-resource peers. Third, students with higher resources have higher quality information both about college quality and their own academic achievement relative to other students; this increases their likelihood of applying to colleges that are a good match for their academic records. Fourth, higher resource students are able to enhance their apparent academic records (analogous to engaging in test preparation or other private tutoring, obtaining help writing college essays, or strategically participating in extracurricular activities, for example). These features of the model are explained and calibrated in Reardon et al. (2016). Reardon et al. (2016) showed that, taken together, imperfect information, idiosyncratic preferences, strategic application behavior, and socioeconomic influences create patterns of college selection and enrollment that are similar to those in the real world.

Each of the 40 colleges in our model has a target enrollment for each incoming class of 150 students, meaning there are a total of 6,000 seats available for each cohort of students. The ratio of total students to total college seats is roughly the same as the proportion of 2002 tenth graders who attended any type of college by 2006.[3] The only attribute that colleges have is quality (perhaps better thought of as *reputation*, though in the real world the two are generally conflated in public perception). Quality is operationalized as the average academic achievement of students enrolled in the school. In the real world, this mean academic achievement is probably correlated with, but not the same as, the quality of educational experience for students at a given college. Quality is measured in the same units as student academic achievement.

The model iterates through three stages during each simulated year: application, admission, and enrollment.[4] During the *application* stage, a cohort of prospective students observes, with some uncertainty, the quality of each of the 40 colleges in a given year and selects a limited number of colleges to which to apply based on their uncertain and somewhat idiosyncratic perceptions of the utility of attending each college and of their probability of admission to each. During this stage, the model can allow some colleges to use race-based recruitment strategies that enhance the perceived utility of

[3] Although all of students in our model apply to colleges, roughly 40 percent are not admitted anywhere because there are fewer seats than students. An alternative model would have students with near-zero probabilities of admission not apply to any colleges. Our results are not sensitive to this modeling choice, however, because these students' applications have no aggregate effect on what type of students are admitted to colleges—the colleges in our model end up with the same students using either approach.

[4] For a more detailed explanation of the agent-based model, see Appendix C.

attending those colleges for targeted students.

More formally, a student decides where to apply based on their perception of their own academic achievement, the perceived quality of a college, the utility of attending a college, and an estimation of the likelihood the student will be admitted to a college. A student perceives their own achievement according to

$$A_s^* = A_s + \alpha_s + e_s; \;\; e_s \sim N(0, \sigma_s),$$

where A_s^* is the student's estimate of how appealing she or he will be to colleges, A_s is the student's actual academic achievement, and α_s is represents the extent to which the students is able to enhance his or her apparent academic achievement (e.g. via SAT® exam coaching or extracurricular participation); this enhancement parameter varies with family resources. Students perceive their own academic achievement with some error, captured by e_s. This term also varies with family resources, such that students with more family resources perceive their academic achievement with less error.

Students observe the quality of colleges according to

$$Q_{cs}^* = Q_c + u_{cs}; \;\; u_{cs} \sim N(0, \tau_s)$$

where Q_{cs}^* is student *S*'s perception of college *C*'s quality, Q_c is the actual quality of each college, and u_{cs} is a random noise term drawn from a normal distribution whose variance is again a function of the student's family resources. This noise captures idiosyncratic preferences for colleges (e.g., a student might be impressed by a college's dormitories or the tour guide) as well as imperfect information on the part students. Higher resource students perceive quality with less noise—they have better information and more uniform preferences about college quality.

U_{cs}^* is the perceived utility of attending college *C* for student *S*. It is given by

$$U_{cs}^* = a_s + b_s(Q_{cs}^*) + R_{sc}.$$

Here a_s and b_s are the intercept and slope of a linear utility function. R_{sc} captures the result of race-targeted recruitment strategies on the part of colleges. This recruitment term is meant to capture the increase in perceived desirability of a college that has made special efforts to recruit minority students, whether through targeted visits to high-minority high schools, strategic disbursement of financial aid, or other methods. R_{sc} is the increase in student *s*' perception of the utility of college *c* that comes from recruitment of *s* by *c*. . If college *c* uses race-targeted recruitment, black and Hispanic students increase their perception of the utility of attending the recruiting school by 50 points (in a light recruitment policy case), 100 points (in a moderate recruitment policy case), or 200 points (in a strong recruitment policy case); this enhanced utility value is used by students when making application and enrollment decisions. Because we use a utility slope (b_s) value of 1 in our simulations, this increase in utility is equivalent to an increase in perceived quality of the same amount. On the college quality scale, 50 points is, across all runs and experiments, roughly equivalent to half a standard deviation. These values were selected to be comparable in magnitude to affirmative action policies that affect colleges' evaluations of students in our simulations (discussed in more detail below). This decision is justified in part by Brown and Hirschman (2006), whose evidence suggests that gains in applications from targeted minority student recruitment were roughly similar to losses in likelihood of admission after race-conscious affirmative action was banned in Washingon.

A student's estimation of her probability of admission to a given college C is given by

$$P_{cs} = f(A_s^* - Q_{cs}^*)$$

where f is a logit function predicting admissions outcomes using the difference between a student's true academic achievement and college quality for each submitted application over the past 5 years. Students apply to the set of colleges $C_1, C_2, \dots, C_{n_s}$ that maximizes $\mathrm{E}_S\left(C_1, C_2, \dots, C_{n_s}\right)$, which can be calculated recursively as:

$$\mathrm{E}_S\left(C_1, C_2, \dots, C_{n_s}\right) = P_{C_i s} U_{C_i s}^* + \left(1 - P_{C_i s}\right) \mathrm{E}_s(C_1, C_2, \dots, C_{n_s} \backslash C_i).$$

This recursive approach is similar to the sequential utility maximization of application choices used by Howell (2010).

Although the model assumes all students are rational, utility-maximizing agents with enormous computational capacity, this is moderated by the fact that the student agents in the model have both resource-related imperfect information and idiosyncratic preferences. This means that there is considerable variability in student application portfolios, even conditional on having the same true academic achievement, and that high-resource students choose, on average, more optimal application portfolios than lower-resource students. Both of these features mimic aspects of actual students' empirical application decisions (e.g., Hoxby & Avery, 2012) and produces very realistic patterns of application (Reardon et al., 2016).

In the *admission* stage, colleges observe the academic records of students in their applicant pools and admit those they perceive to be most qualified, up to a total number of students that colleges believe will be sufficient to fill their available seats based on yield information from previous years. In the calculation of how many students to admit, colleges consider the total number of seats they want to fill (150 in all cases) and a three-year running average of yield—the percentage of admitted students who enroll—and will admit as many students as they think they need to fill their seats exactly. Like students, colleges view the world with some uncertainty and idiosyncrasy. This means, for example, that colleges do not rank students identically, reflecting the reality that different colleges have different preferences for students.

Formally, a college's assessment of the admissions desirability of a given student is represented by

$$A_{cs}^{**} = A_s + \alpha_s + w_{cs} + T_c[G \cdot (Black_s | Hispanic_s) + HR_s]; \;\; w_{cs} \sim N(0, 100^2).$$

That is, a college perceives the actual academic achievement of a student, A_s, plus any strategic enhancement of the student's academic achievement, α_s (described above), with a certain amount of noise w_{cs}. The standard deviation of this noise term is half a standard deviation of the academic achievement scale, implying that colleges can discern students' academic achievement (including any enhancement effects) with a reliability of 0.8.

It is during the calculation of A_{cs}^{**} that colleges with an affirmative action policy apply additional weight to a student's perceived admissions desirability in accordance with that policy. This additional weight is captured by the term $T_c[G \cdot (Black_s|Hispanic_s) + HR_s]$. In this term, T_c indicates whether a college has an affirmative action policy, G is the size of the race weight given to a student if they are Black or Hispanic for colleges using race-based affirmative action. H is the size of the weight given to students under SES-based affirmative action policies, which is applied linearly in accordance with the student's resources, R_s. The size of the affirmative action weights we use are based on our estimate of a 1.3 standard deviation relative race weight evident in selective admissions, described above. Given this estimate, we establish a "moderate" race-based affirmative action policy that gives a 0.75 standard deviation, or 150 points on our academic achievement scale, weight to Black or Hispanic students. Likewise, we assign a 300 point weight in a "strong" affirmative action policy. Thus, strong racial affirmative action is slightly stronger than the average used by highly selective colleges today; moderate racial affirmative action is roughly half as strong.

Likewise, moderate and strong SES-based affirmative action gives students an implicit weight of plus or minus 75 or 150 points, respectively, for each standard deviation they are above or below the average student in resources. We chose these values to ensure that our simulations represent a significant increase over current practice in SES-based affirmative action so that they represent a plausible test of what might occur if colleges begin weighting SES much more heavily than they do at present. Moreover, while the magnitude of these SES-based affirmative action weights is half that of the corresponding race weights, recall that the SES weight is assigned per standard deviation of family resources. Because of this approach, the difference in weights between students +/- 1 standard deviation from the average resource level is 300 achievement points in the strong policy case.

Finally, in the *enrollment* stage, students compare the colleges to which they have been admitted and enroll in the one with the greatest perceived utility (U_{cs}^{*}). At the end of each simulated year, each college's quality (or reputation) is updated by taking a weighted average of prior college quality and the average academic achievement of the newest cohort of enrolled students (where prior quality has a weight of 0.9 and the new cohort has a weight of 0.1). Likewise, colleges update their yield estimates with the three most recent years of admissions data. These three stages are repeated in the next year with a new set of 10,000 students and the same set of colleges.

We simulated admission and enrollment patterns across multiple different parameter combinations: a baseline scenario in which no college used any form of affirmative action; six scenarios in which the top four colleges used one of six different versions of affirmative action (AA) policies: (a) no racial AA and moderate SES AA, (b) no racial AA and strong SES AA, (c) moderate racial AA and no SES AA, (d) strong racial AA and no SES A, (e) moderate racial AA and moderate SES AA, and (f) strong racial AA and strong SES AA; and nine scenarios where the top four colleges used varying levels of SES-based affirmative action with varying levels of race-based recruiting.

Although empirical observation of college admissions in the ELS dataset suggests that roughly the most selective 10 percent of colleges employ racial affirmative action policies, we experimented with different numbers of colleges using moderate race-and-SES-based affirmative action in order to explore dynamic system-wide effects that result from different numbers of colleges using these policies. For these experiments, we included scenarios where the top one, four, 10, 20, or all 40 colleges use affirmative action in admissions; we also included a scenario where four of the top 10 colleges (those initially ranked 1, 4, 7, and 10) use affirmative action. These simulations allowed us to examine how differences in the proportion of colleges using affirmative action policies might affect admissions and enrollment patterns.

In each scenario, we allowed the model to run for 30 simulated years in two 15-year phases. The simulation is not intended to represent 30 historical years; the analytic focus is on simulation end states, and not trends. The first 15 years are a conservatively long "burn-in" period in which no college used any affirmative action policy; this allowed the model to consistently settle into a state in which dynamic elements in the model (i.e. colleges' quality values, colleges' expected yield) are largely stable from one year to the next. After the 15-year burn-in period, the specified colleges started to use affirmative action strategies, and the model then ran for an additional 15 years. Within five to eight years of using affirmative action strategies, college quality and enrollment patterns stabilize again. To be conservative, and to allow for the emergence of dynamic effects, we allow the model to run through year 30 and then use the average patterns of enrollment in the final five years (years 26 through 30) to assess the effects of each affirmative action scenario. We describe the racial and socioeconomic composition of each college in this period to assess the policy effects on college racial and socioeconomic diversity (in colleges both using and not using some form of affirmative action). In addition, in order to assess whether affirmative action produced academic mismatch for minority students, we describe the average high school academic achievement of students in the colleges of students of a given race or level of family resources. Finally we look at the effects of affirmative action policies on diversity and quality of both colleges that do and do not use affirmative action. To account for potential idiosyncrasies within a given simulation of a scenario, we simulate each scenario ten times, and average across these ten iterations to capture the college and student outcomes of interest.

RESULTS

We start by comparing the effects of race- and SES-based affirmative action policies on the racial and socioeconomic composition of the top colleges. For this portion of the analysis, we focus on the scenarios when the top-four colleges use affirmative action policies. Figure 2 shows the racial composition among the four colleges that use affirmative action by simulated affirmative action policy. The proportion of Black and Hispanic students is positively affected by both types of affirmative action policies but increases more strongly when the magnitude of racial affirmative action increases than when the magnitude of socioeconomic affirmative action does. This finding is evident when one compares the rate of change in the proportion of minority students in scenarios 1, 2, and 3, where we have increasing race-based affirmative action and no SES-based affirmative action, with the rate of change in the proportion of minority students in scenarios 1, 4, and 5, where we have increasing SES-based affirmative action with no race-based affirmative action. Scenario 3, which presents results when colleges use “strong” race-based but no SES-based affirmative action, is most analogous, albeit slightly stronger, to what would be seen under our estimated “real world” race-based affirmative action weight. Scenarios 6 and 7 show that colleges are most racially diverse when both race- and SES-based affirmative action policies are used.

[Figure 2 here]

Figure 3 shows the socioeconomic composition, in terms of student resource quintiles, of colleges that use affirmative action by simulated affirmative action policy. SES-based affirmative action policies have a large effect on the socioeconomic composition of colleges with stronger SES-based policies producing more SES diversity. Racial affirmative action policies, on the other hand, have a small effect on SES diversity, especially relative to that of socioeconomic affirmative action policies. The first quintile students—those with the lowest level of resources—experience the greatest gain in overall enrollment rate under both race and SES-based affirmative action strategies. Conversely, the highest quintile experiences the greatest reduction in enrollment. There are only small changes in enrollment for the second, third, and fourth quintiles across all scenarios.

[Figure 3 here]

Figure 4 shows the racial composition among the four colleges that use affirmative action by simulated SES-based affirmative action and race-based recruitment policy. Within each category of SES-based affirmative action (none, moderate, and strong), increasing the strength of race-based recruitment positively affects the proportion of Black and Hispanic students enrolled in the top colleges. The effect of recruitment increases as the strength of SES-based affirmative action increases; this is evident when comparing the percentage change in minority enrollment from scenarios 1 to 3 (2 percent increase) to the change from scenarios 7 to 9 (7.8 percent increase). Notably, certain combinations of race-based recruiting and SES-based affirmative action result in similar levels of Black and Hispanic enrollment to moderate and strong race-only affirmative action (see Figure 2). For example, moderate recruiting combined with moderate SES-based affirmative action results in a similar racial composition as moderate race-based affirmative action alone; strong SES-based affirmative action with moderate recruiting results in similar levels as strong race-based affirmative action alone. Appendix A contains a figure showing the socioeconomic composition of colleges that use SES-based affirmative action and race-based recruiting; race-targeted recruitment does not meaningfully affect socioeconomic composition.

[Figure 4 here]

Next we turn to how affirmative action policies affect the difference in academic achievement between the beneficiaries of affirmative action and the other students enrolled in their college. Figure 5 shows mean academic achievement of students' classmates in college as a function of a student's own achievement, race, and affirmative action type. Here again, only the top four colleges in the simulation use affirmative action, although we examine the effects of these policies on all students enrolled in colleges. Race-based and the combination of race- and SES-based affirmative action policies lead Black and Hispanic students to enroll at colleges where their peers have higher average academic records relative to no race- or SES-based affirmative action policies alone (Figure 5, right panel). This increase in the mean academic achievement of peer students is experienced through most of the achievement distribution for Black and Hispanic students and amounts to as many as 40 academic achievement points (roughly 0.2 standard deviations). This consistent increase in mean achievement is evidence that, on average, minority students experience modestly better academic settings under affirmative action policies. This boost is also evident for high-achieving minority students—those with academic achievement above 1200—in colleges that use both SES-based affirmative action and race-based recruiting; moderate-achieving minority students (<1200), however, do not experience the same increase in peer achievement. The left panel shows that White students experience small decreases in the mean academic achievement of their peers under all types of affirmative action, although this decrease is only appreciable under the joint SES- and race-based affirmative action policies, and only at the high end of the student academic achievement distribution. On average, most White students do not experience any meaningful changes to their academic environment as an effect of affirmative action or recruitment policies.

[Figure 5 here]

Figure 5 also includes a 45-degree line, which indicates when a student's own achievement is equal to the average achievement of his or her peers. A student's own achievement falls below the average achievement of his or her peers when the lines of the figure are above the 45-degree line. Under no affirmative action, and SES-only affirmative action, the average minority student with achievement of 1060 (0.3 standard deviations above the population mean achievement of 1000) or less have academic achievement lower than that of her or his classmates (Figure 5, right panel). This pattern is not race-specific: the average White student with achievement of 1060 or below is likewise overmatched by her or his peers (Figure 5, left panel). However, under race- and combination race- and SES-based policies, the average minority student with achievement below roughly 1100 attends a school his or her achievement falls below the schoolwide average. Thus, our race-based affirmative action scenarios do lead to a slight increase in the average differences between a minority student's achievement level and those of his or her schoolmates, though this increase is generally small. There is no scenario where the average moderately high-achieving minority student—a student with higher than 1100 achievement—enrolls in a school where his or her achievement is below the average achievement of the other students in the same college. Whether overmatching is extreme enough that it leaves students academically over their head is beyond the scope of this paper. The set of policies that result in the least amount of minority overmatch is SES-based affirmative action with race-based recruitment.

Analogous patterns are evident in Figure 6, which shows the mean academic achievement of enrolled students as a function of student academic record, low or high SES, and type of affirmative action policy. Low-SES students (right panel) experience an increase in the mean academic achievement of their peers under any affirmative action policy that utilizes SES (including race-based recruitment) but only minor increases as a result of race-based affirmative action. This increase is relatively consistent in the upper two-thirds of the student academic achievement distribution, with the largest increases for the average student with achievement above 1200. High-SES students (left panel), however, see a decline in the mean academic achievement of their peers under all affirmative action policies, particularly for the combined SES- and race-based policy. Although these decreases are not large through much of the student achievement distribution, they do increase as student academic achievement increases; at the high end of the student achievement distribution, the decrease is as much as 40 points (0.2 standard deviations of the achievement distribution) under the joint race- and SES-based affirmative action policies. Note that Figure 6 (right panel) also shows little evidence that race-based affirmative action changes the average performance of the peers in the schools where low-SES students enroll; it does not appear to induce any new overmatching.

[Figure 6 here]

Figure 7 describes the mean high school academic achievement of one's classmates by one's own high school achievement and race under scenarios where moderate race-based affirmative action policies are used by different numbers of colleges. For White students (Figure 7, left panel), there is little difference in the mean achievement of peers depending on which schools use affirmative action admissions policies; the lines are close throughout the distribution. For minority students (right panel), however, there are increases in the mean achievement of their peers under all affirmative action policies; these gains are evident across the majority of the student achievement distribution. As one might expect, when only one college uses affirmative action, only students in the top of the achievement distribution experience different peer achievement as a result, whereas when 10 colleges use these admissions policies, minority students across the distribution experience higher-achieving peers.

[Figure 7 here]

Because students and colleges comprise an interconnected system, the effects of affirmative action policies will not be isolated to the colleges that use them. Colleges that do not use affirmative action policies are affected by the presence of such policies in other schools. Figure 8 illustrates these system dynamics—the effect of having either one or four colleges using affirmative action policies on the kinds of students (achievement and race) enrolled in all colleges.[5] In each of the panels, black arrows indicate the colleges that use affirmative action and gray arrows show colleges that do not. Each of the arrows starts at the location in the figure corresponding to the racial composition and average high school academic achievement of enrolled students in the college in the final year of the model's burn-in period (year 15), before any college begins using affirmative action. The arrows end at the location corresponding to each college's enrollment composition in the final year of the model (year 30), after some colleges in the model have been using moderate race- and SES-based affirmative action for 15 years.

A few results are immediately clear in Figure 8. First, colleges that use affirmative action move up and to the left in the figures. That is, these colleges become more racially diverse and their students' average achievement declines slightly. Second, the slope of these black arrows is quite steep, which indicates that the changes in mean achievement are much less pronounced than the changes in the proportion of minority students. Evident in these graphs, and even more evident in the graphs in

[5] We present the one and four college results because they are most analogous to patterns of affirmative action use in the real world. In Appendix E we present similar figures for the effects on minority and low-income enrollment of different numbers of schools using affirmative action policies. The effects on the proportion of low-income students in each school are qualitatively similar, so we include only race outcomes here.

Appendix E, the less selective colleges that use affirmative action experience the greatest changes in both diversity and average achievement—their lines move the farthest. Third, colleges that do not adopt affirmative action policies but that are close in quality to those that do also experience significant changes in diversity and average achievement, though in the opposite direction as those using affirmative action. That is, they become less diverse and the mean achievement of their enrolled students increases. Fourth, the effects on colleges that use affirmative action vary relatively little by the number of colleges using affirmative action; once a school is using these admissions policies it seems to matter little whether colleges near it in quality are also using them. Finally, the margin of college attendance is generally unaffected by affirmative action policies; the characteristics of unenrolled students (the left-most arrow) remain mostly unchanged.[6]

[Figure 8 here]

DISCUSSION

The results of our simulations suggest at least four important patterns: (a) even relatively aggressive SES-based affirmative action policies do not mimic the effects of race-based policies on racial diversity; likewise race-based affirmative action policies do not mimic the effects of SES-based policies on SES diversity; (b) SES-based affirmative action in combination with targeted recruitment shows the potential to be comparable to race-based affirmative action on its own; (c) there is little evidence that, for minority students, race-based policies lead to differences in the average achievement of their college peers that are notably greater than the differences we observe under SES-based affirmative action or scenarios with no affirmative action of any type; and (d) the use of affirmative action policies by some colleges reduces the diversity of similar-quality colleges that do not have such policies.

The 2013 *Fisher* decision requires universities to prefer "workable race-neutral alternatives" to

[6] In Appendix E, we show that this is true up until at least half of colleges use affirmative action, then the population of students not enrolled in college includes notably fewer minority students and has higher mean achievement.

race-based affirmative action. Suggesting one such alternative, Kahlenberg (1996) has argued that “class-based preferences provide a constitutional way to achieve greater racial and ethnic diversity” (p. 1064). However, our simulations suggest that unless SES-based affirmative action policies use a very strong preference for lower SES students, or are paired with effective race-based recruitment efforts, these policies are unlikely to result in the same racial composition in colleges as under current race-based affirmative action policies. These results are consistent with Sander (1997), who found that SES-based affirmative action at the UCLA law school did not produce the levels of diversity achieved under race-based affirmative action policies, and Long (2015) who found in Texas that that any number of race proxies could not reproduce the diversity achieved under race-based affirmative action.

Perhaps unsurprisingly, affirmative action policies generally produce only results they are explicitly designed to produce. For SES-based affirmative action policies to produce racial diversity (and race-based policies to produce SES diversity), then, the correlation between SES and race must be very high. Our analysis makes clear that the correlation currently observed in the real world is not high enough to make SES-based affirmative action a realistic alternative to race-conscious admissions policies. This is not to say that the correlation isn’t high—it is—however, it is not high enough that one can be used as a proxy for the other in affirmative action policies. This conclusion is consistent with the ineffectiveness of SES-based K–12 school integration policies at producing racial integration (Reardon et al., 2006; Reardon & Rhodes, 2011).

Because SES-based affirmative action is effective at increasing SES diversity, colleges who consider such policies will have to consider what those policies will mean in terms of the additional students the policy will bring in who need financial aid. Currently, very few colleges are able to meet the full demonstrated financial need of the students they enroll without SES-based affirmative action, so an additional influx of lower-income students would likely stretch limited resources even more thinly. Moreover, our models assume that cost is not a barrier to enrollment for low-income admitted students.

In the absence of additional financial aid, SES-based affirmative action policies will increase the number of low-income students who are admitted to a college, but may not have the same effect on enrollment patterns, because cost will be a barrier for some of the additionally-admitted low-income students. That is, our estimates may overstate the effects of SES-based affirmative action policies unless such policies were coupled with increased financial aid. In contrast, race-based affirmative action alone yields higher proportions of underrepresented minority students in the top colleges, although it produces relatively little additional socioeconomic diversity. In this respect, it is likely a less expensive and more direct means of increasing the racial diversity of colleges.

The middle ground of SES-based affirmative action plus targeted race-based recruitment and outreach offers a tempting solution to bans on race-conscious admissions policies. Our simulations show that such combined policies, if each is sufficiently strong, can be as effective as race-conscious admissions on its own. Indeed, targeted recruitment without SES-based affirmative action appears to have stemmed the loss of minority students at the University of Washington after the state banned race-conscious affirmative action in admissions (Brown & Hirschman 2006). However, the results of such efforts in California are less clear (Gándara, 2012; Geiser & Caspary 2005). In fact, despite doubling its recruitment budget, California still saw a substantial proportion of high-achieving minority students enroll in colleges outside the California system, even if they were admitted (Geiser & Caspary 2005).

Such findings call into question whether outreach and recruitment efforts can sway minority students enough to make a difference to campus diversity. Our models assumed that, at a minimum, colleges could raise their appeal to students by 50 points (comparable to the average SAT® score at a college appearing 50 points higher). Further, our model was 100 percent efficient—all minority students felt the effect of our recruitment mechanism. It is hard to judge whether these assumptions carry much veracity in the real world—Washington appears to have been successful, but the results in California were mixed.

At the very least, the effort required to boost minority student recruitment efforts will only add to the cost of SES-based affirmative action programs. In other words, SES-based affirmative action plus race-targeted recruitment and outreach is a race-neutral alternative to race-conscious affirmative action, but it is not clear whether institutional budgets at public universities make it “workable.”

Our models also suggest that affirmative action policies are unlikely to change the margin of college attendance. That is, they do not have much effect on who attends college, but only on which college they attend if they do. Unless affirmative action policies are targeted at much lower achieving students or are implemented much more widely than they currently are, these policies are unlikely to affect the overall racial and socioeconomic distribution of college attendees.

Critics of race-based affirmative action have argued that it can lead to academic mismatch for minority students. We find that race-based affirmative action, alone or in combination with SES-based affirmative action, very modestly increases the extent to which the average minority student has achievement levels below those of their college classmates. These results are in line with those of Arcidiacono et al. (2014), who found that affirmative action in California appeared to increase academic over-match. Note that our results describe the experience of the *average* student at *all* colleges regardless of whether the college uses affirmative action. This approach may understate the extent of overmatch induced by affirmative action policies at schools that utilize affirmative action. The simulation is not able to speak to the effect that this modest increase in average over-match might have on student outcomes. Recent empirical evidence (Dillon and Smith 2015) suggests that academic mismatch has only trivial negative effects on students.

Finally, we also considered how the redistribution of students by affirmative action policies affected all colleges, not just the colleges that use the policies. System dynamic effects are an important, and often overlooked, factor in affirmative action policies; because colleges and students are operating in an interconnected and interdependent system, the policies of one college can affect all colleges. Building on the work of Long & Tienda (2010) in Texas, we find that these effects are particularly strong for colleges that are not using affirmative action policies but are close in quality to schools that are. This result could be a particularly important dynamic in states in which public colleges are unable to use race-based affirmative action but private colleges of similar quality continue to use race conscious admissions policies. This suggests that any complete assessment of affirmative action policies must attend to effects not only within colleges that use affirmative action, but also those that do not.

The models presented in this paper do not directly address issues of cost or financial aid. We do, however, indirectly include elements of race-targeted financial aid in our recruitment parameters: financial aid and other forms of tuition discounting are implied in efforts that would make a college more desirable to targeted students. However, it is likely that the direct inclusion of cost and financial aid considerations would mute some of the effects of affirmative action policies unless the policies are accompanied by increased financial aid or other greatly modified tuition structures. Minority and low income students would presumably be discouraged from applying to expensive, selective colleges, limiting the ability of affirmative action policies of any type to be effective. Our results, therefore, may represent an upper bound on the potential effectiveness of various affirmative action polies. The complexities of this issue are worth exploring in future research and are an area to which policy makers should pay close attention.

In *Fisher*, the Supreme Court challenged states and universities to find race-neutral strategies that can achieve educationally-beneficial diversity. Racial diversity is, the court has agreed, educationally beneficial (*Grutter v. Bollinger*, 2003). The question, then, is how best to achieve such diversity in constitutionally permissible ways. Perhaps the best way would be to eliminate racial gaps in high school achievement and graduation rates; doing so would certainly go a long way toward equalizing access to selective colleges and universities without the need for race-based affirmative action. Although these gaps have narrowed moderately in the last two decades (Reardon, Robinson-Cimpian, & Weathers, 2015;

Murnane, 2013), they are still very large, without a clear indication that they will be eliminated any time soon.

Until racial disparities in educational preparation are eliminated, then, colleges need other strategies to achieve diversity goals. Our analysis here suggests that affirmative action policies based on socioeconomic status are unlikely to achieve meaningful increases in racial diversity. That is not to say that socioeconomic affirmative action would not be valuable in its own right—it would increase socioeconomic diversity on university campuses and would benefit low-income college applicants—but only that it is not an effective or efficient means to achieving racial diversity. Race-conscious affirmative action does, however, increase racial diversity effectively at the schools that use it. Although imperfect, it may be the best strategy we currently have.

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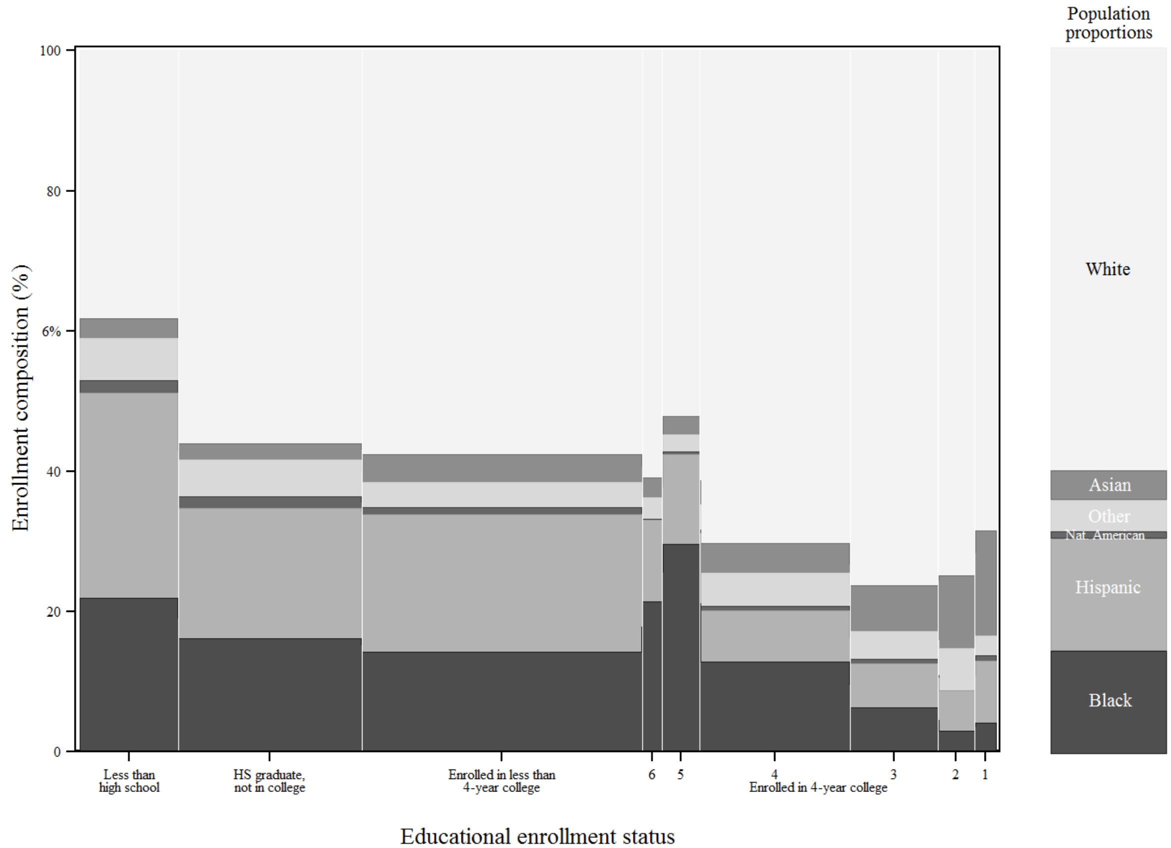
Table 1. Agent-Based Simulation Model (ABM) Parameters

Parameter	Value	Source
Number of students	10,000	n/a
percent White	60 percent	NCES Common Core of Data, 2012
percent Black	15 percent	NCES Common Core of Data, 2012
percent Hispanic	20 percent	NCES Common Core of Data, 2012
percent Asian	5 percent	NCES Common Core of Data, 2012
Number of colleges	40	n/a
College capacity	150 students/college	n/a
Student academic achievement		ELS
White	*achievement~N(1052, 186)*	
Black	*achievement ~N(869, 169)*	
Hispanic	*achievement ~N(895, 185)*	
Asian	*achievement ~N(1038, 202)*	
Student resources		ELS
White	*resources~N*(.198, .657)	
Black	*resources~N*(-.224, .666)	
Hispanic	*resources~N*(-.447, .691)	
Asian	*resources~N*(.012, .833)	
Resources-achievement correlations		ELS
White	*r*=0.395	
Black	*r*=0.305	
Hispanic	*r*=0.373	
Asian	*r*=0.441	
Quality reliability (how well students see college quality)	0.7 + *a*(*resources*); *a*=0.1	Reardon et al., 2016
Own achievement reliability (how well students see their own achievement)	0.7 + *a*(*resources*); *a*=0.1	Reardon et al., 2016
Achievement reliability (how well colleges see student achievement)	0.8	Reardon et al., 2016
Apparent achievement (perceived achievement, increased or decreased through achievement enhancement)	*perceived achievement* + *b*(*resources*); *b*=0.1	Becker, 1990; Buchmann, Condron, & Roscigno, 2010; Powers & Rock, 1999; Reardon et al., 2016
Number of applications	4 + INT[*c*(*resources*)]; *c*=0.5	ELS
Utility of college attendance	*d* + *e*(*perceived quality*); *d*=-250, *e*=1	Reardon et al., 2016

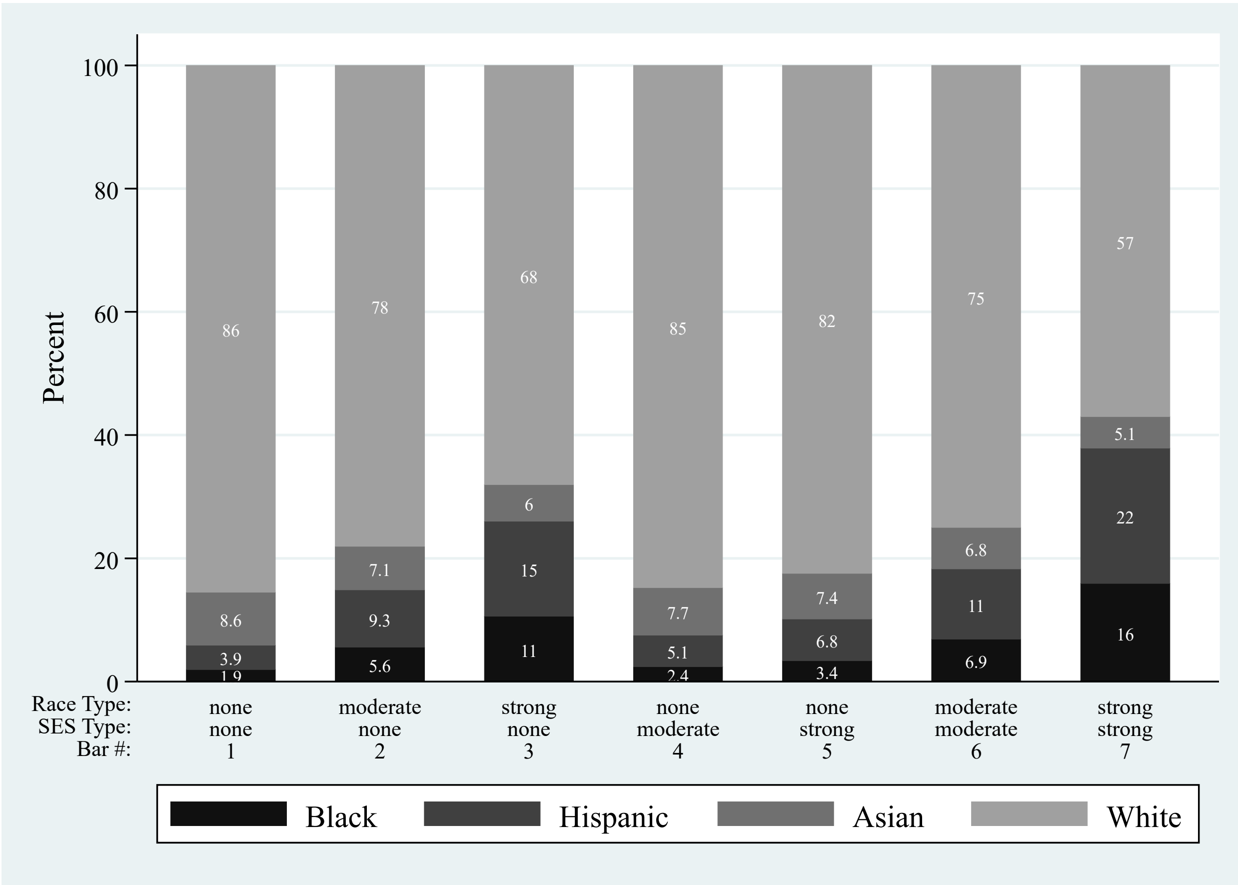
Note. Quality and achievement reliability bound by minimum values of 0.5 and maximum values of 0.9. ELS = Educational Longitudinal Study.

Figure 1. The racial composition of postsecondary destinations for the Class of 2004.



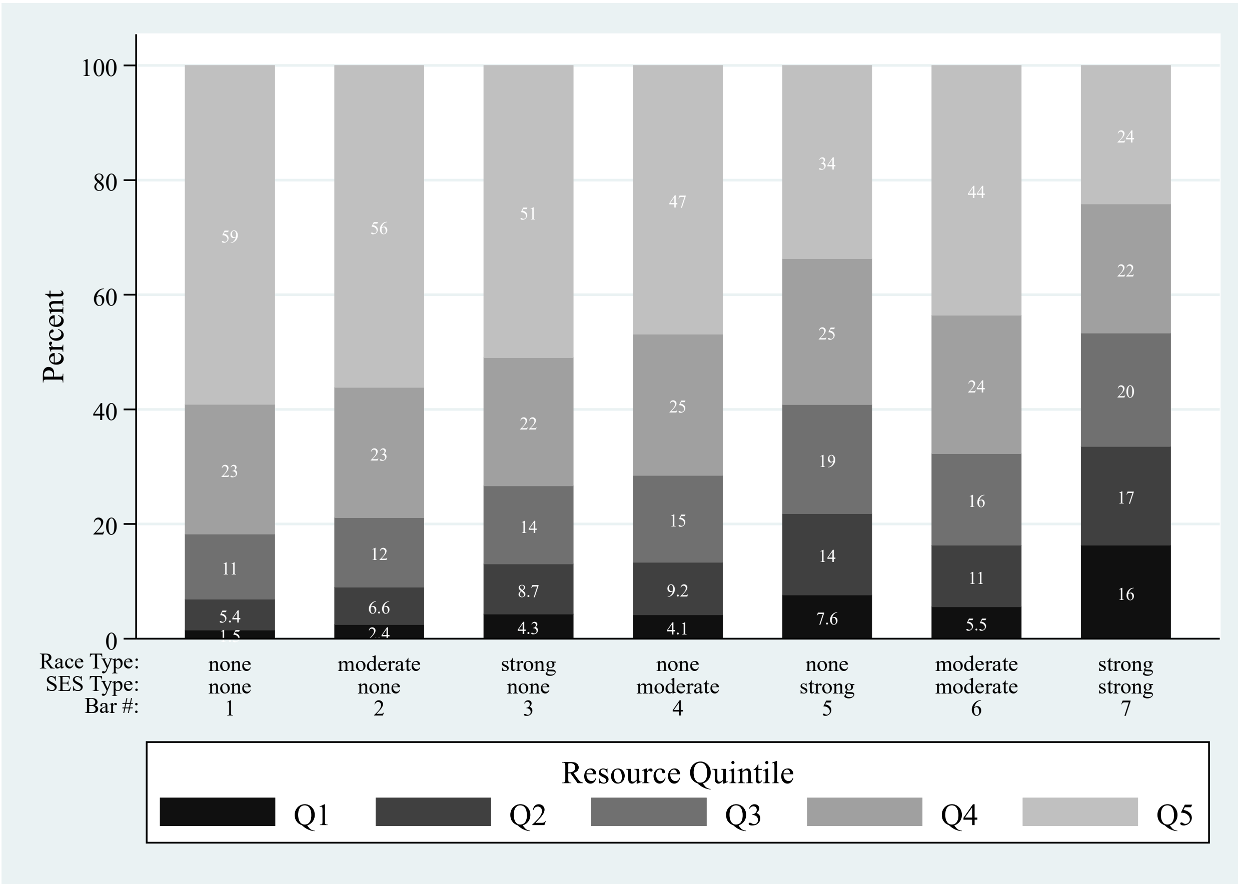
Notes. Reproduced from Reardon, Baker, & Klasik (2012). Figure shows the postsecondary enrollment status of members of the high school class of 2004 by race and type of college or university. The width of each bar represents the percentage of the college-age population enrolled in different types of colleges and universities (or not enrolled in any college, in the case of the leftmost bars); the vertical dimension describes the racial composition of students enrolled in each type of postsecondary institution. Source: Educational Longitudinal Study, 2002.

Figure 2. The racial composition of colleges using affirmative action, by affirmative action type.



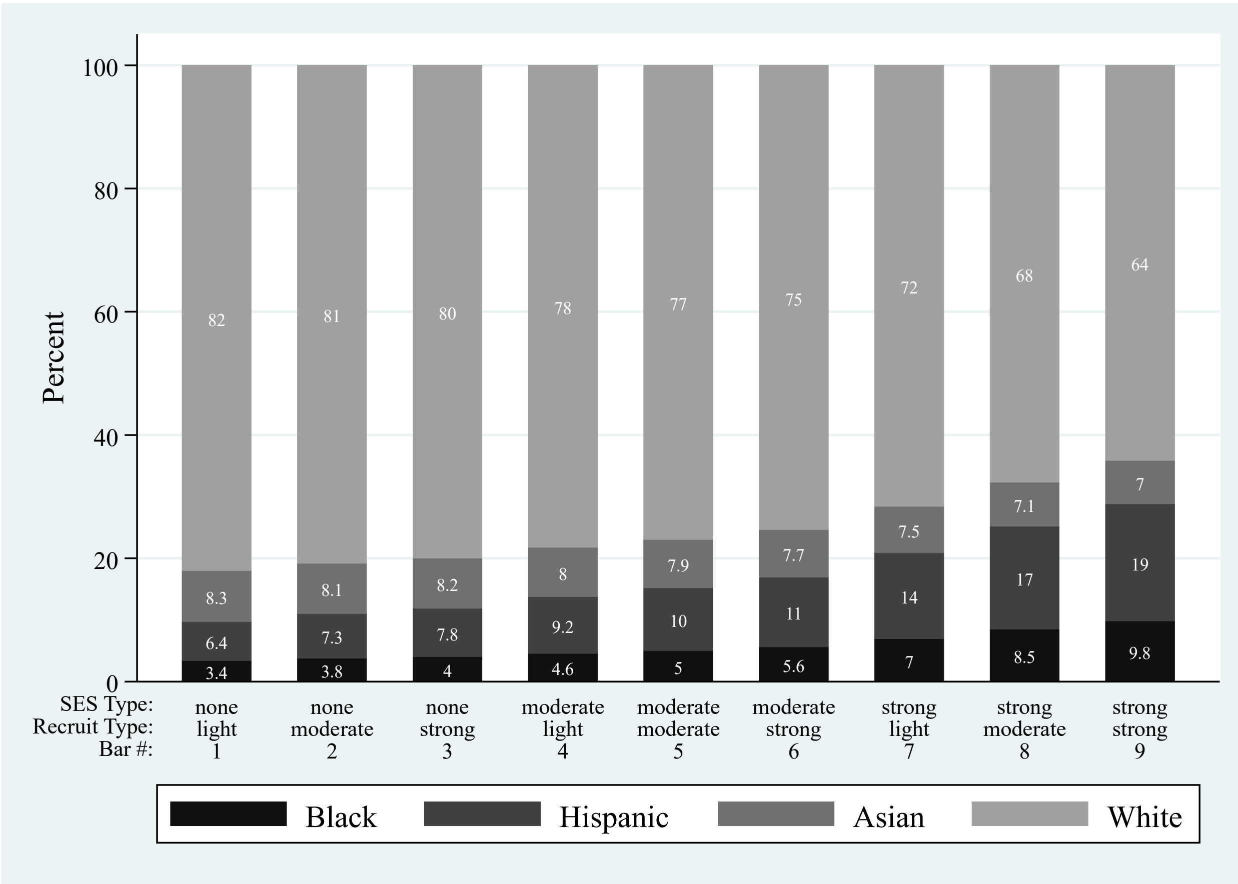
Notes. Simulated population proportions are: 60 percent White, 20 percent Hispanic, 15 percent Black, and 5 percent Asian. Moderate and strong race-based affirmative action scenarios utilize a weight equivalent to 150 and 300 achievement points. Moderate and strong SES-based affirmative action scenarios utilize a weight equivalent to 75 and 150 achievement points per standard deviation of resources. Bar 3 is most analogous to using the estimated real world affirmative action race weight of 260 achievement points. SES is socioeconomic status. Source: authors' simulation.

Figure 3. The socioeconomic composition of colleges using affirmative action, by affirmative action type.



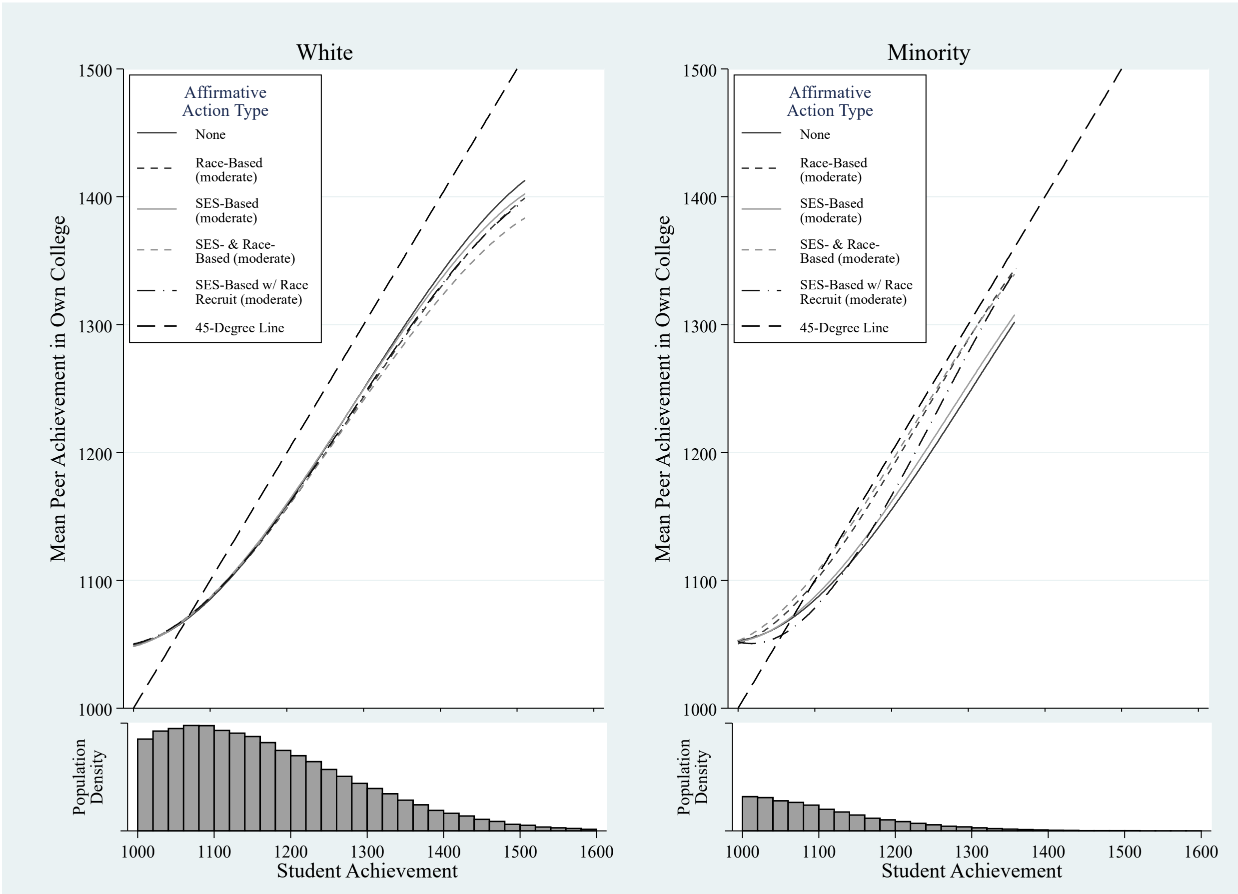
Notes. Moderate and strong race-based affirmative action scenarios utilize a weight equivalent to 150 and 300 achievement points. Moderate and strong SES-based affirmative action scenarios utilize a weight equivalent to 75 and 150 achievement points per standard deviation of resources. Bar 3 is most analogous to using the estimated real world affirmative action race weight of 260 achievement points. SES is socioeconomic status. Source: authors' simulation.

Figure 4. The racial composition of colleges using SES-based affirmative action and race-based recruitment, by affirmative action and recruitment strength.



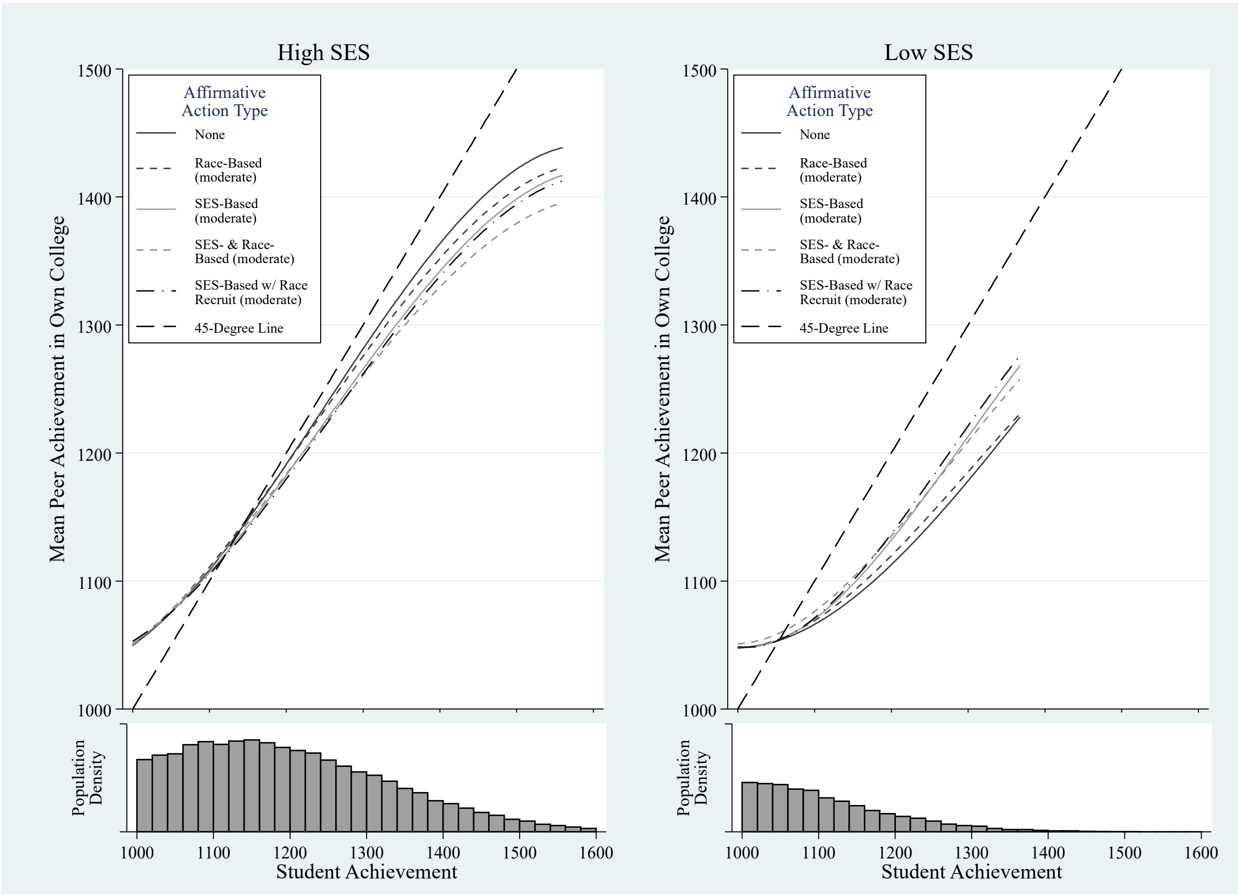
Notes. Simulated population proportions are: 60 percent White, 20 percent Hispanic, 15 percent Black, and 5 percent Asian. Moderate and strong SES-based affirmative action scenarios utilize a weight equivalent to 75 and 150 achievement points per standard deviation of resources. Recruitment weights are: light, 50 points; moderate, 100 points; strong, 200 points. SES is socioeconomic status. Source: authors' simulation.

Figure 5. Mean achievement of students in own college by race and affirmative action type; top four ranked schools use affirmative action.



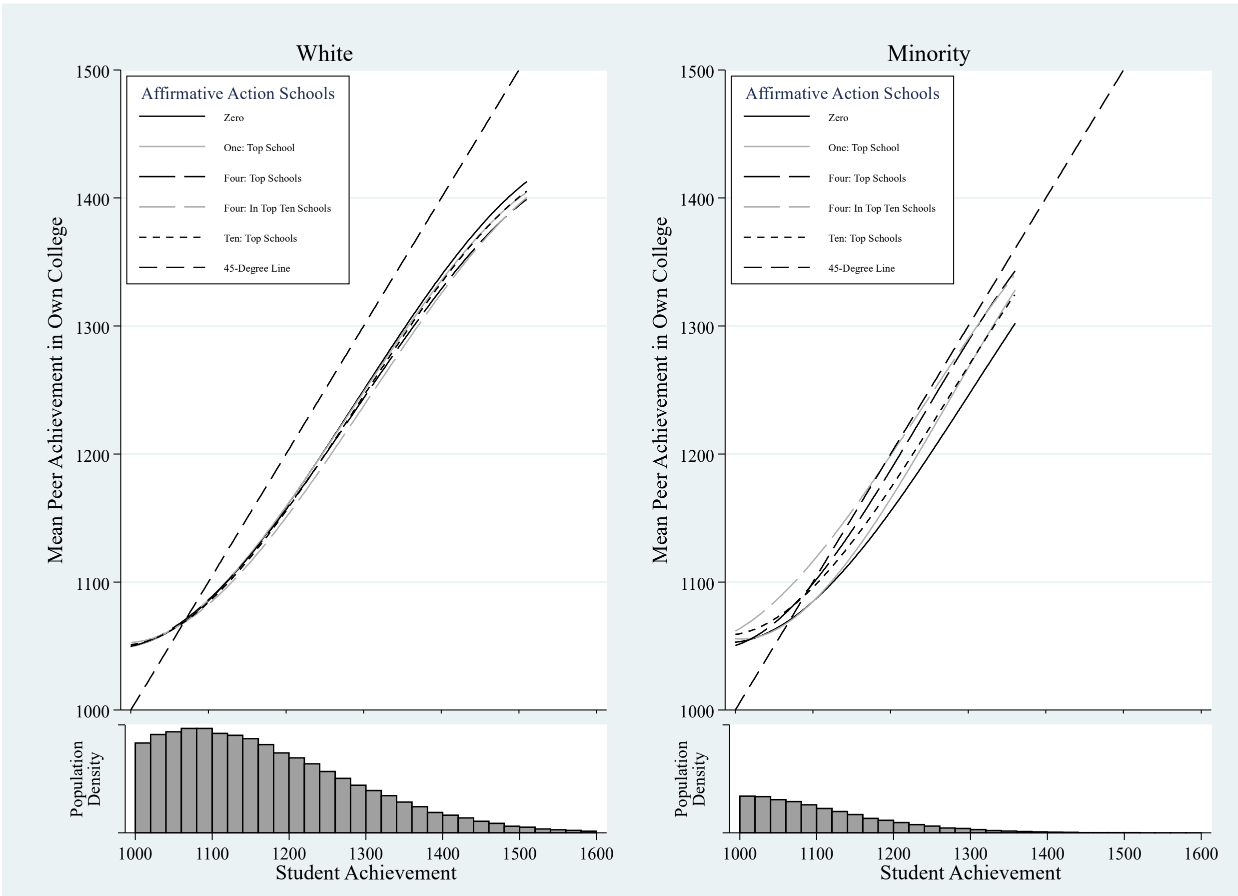
Notes. Figure 5 shows the mean peer achievement of students in own college by race and affirmative action type for all schools and students in the simulation; only the four highest ranked colleges use affirmative action or recruitment. Consider White students (left panel) with achievement scores of 1400. This figure shows that these students attend schools where their peers' average achievement is approximately 1340 when there is no affirmative action or recruitment used. These same students have peers with a slightly lower mean achievement under the combination of race- and SES-based affirmative action. When these lines are below the 45-degree line, students have higher achievement than the average achievement of their peers; conversely, when these lines are above the 45-degree line, students are in settings where their own achievement is lower than the average achievement of their peers. SES is socioeconomic status. Source: authors' simulation.

Figure 6. Mean achievement of students in own college by socioeconomic status (SES) and affirmative action type for the top four schools that use affirmative action.



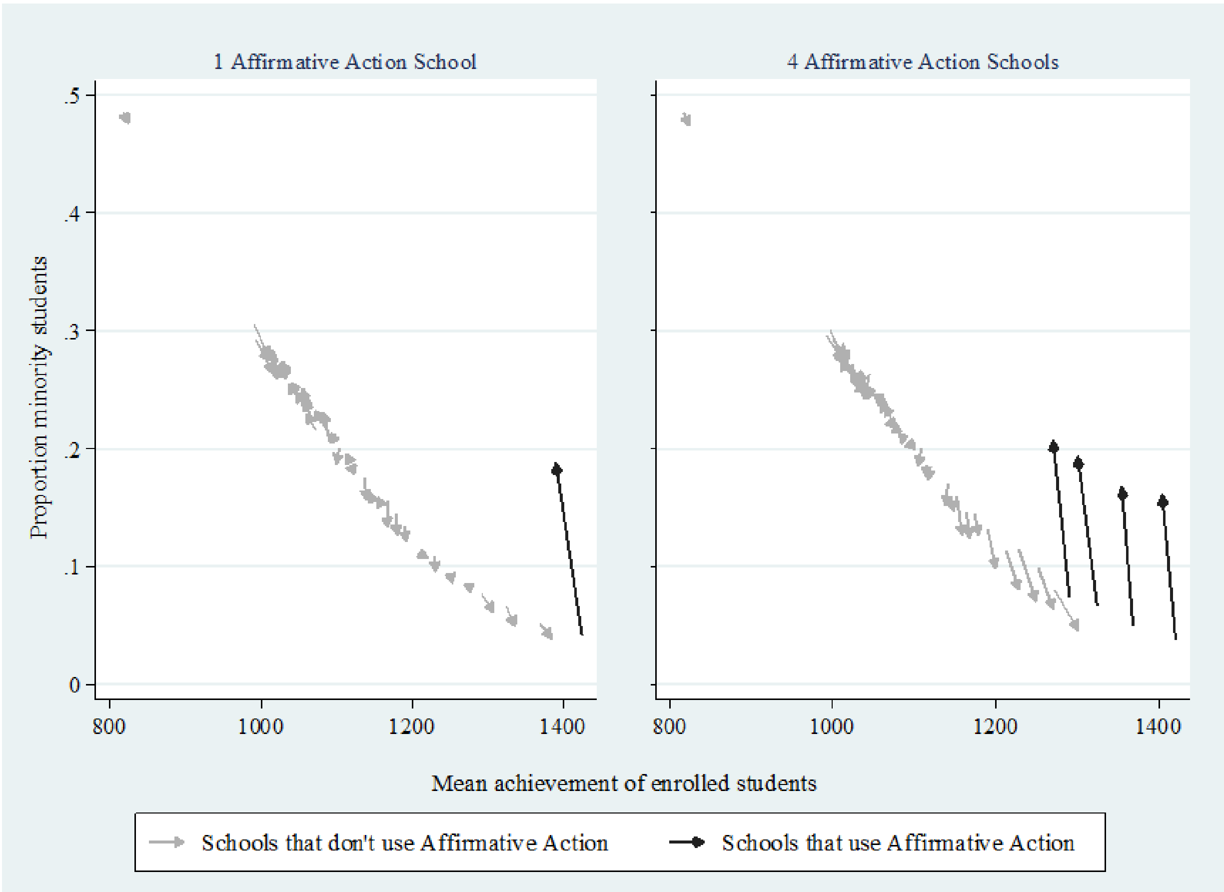
Notes. Figure 6 shows the mean peer achievement of students in own college by SES and affirmative action type for all schools and students in the simulation; only the four highest ranked colleges use affirmative action or recruitment. Consider high-SES students (left panel) with achievement scores of 1400. This figure shows that these students attend schools where their peers' average achievement is approximately 1350 when there is no affirmative action or recruitment used. These same students have peers with a slightly lower mean achievement under any type of affirmative action or recruitment regime. When these lines are below the 45-degree line, students have higher achievement than the average achievement of their peers; conversely, when these lines are above the 45-degree line, students are in settings where their own achievement is lower than the average achievement of their peers. SES is socioeconomic status. Source: authors' simulation.

Figure 7. Mean achievement of students in own college by race and number of affirmative action schools with moderate race-based affirmative action.



Notes. Figure 7 shows the mean peer achievement of students in own college by race and number of schools using moderate race-based affirmative action. As an example of how to read this figure, consider minority students (right panel) with achievement scores of 1300. This figure shows that these students attend schools where their peers' average achievement is approximately 1230 when there is no affirmative action or recruitment used. These same students have peers with a higher mean achievement when any number of schools use affirmative action. When these lines are below the 45-degree line, students have higher achievement than the average achievement of their peers; conversely, when these lines are above the 45-degree line, students are in settings where their own achievement is lower than the average achievement of their peers. SES is socioeconomic status. Source: authors' simulation.

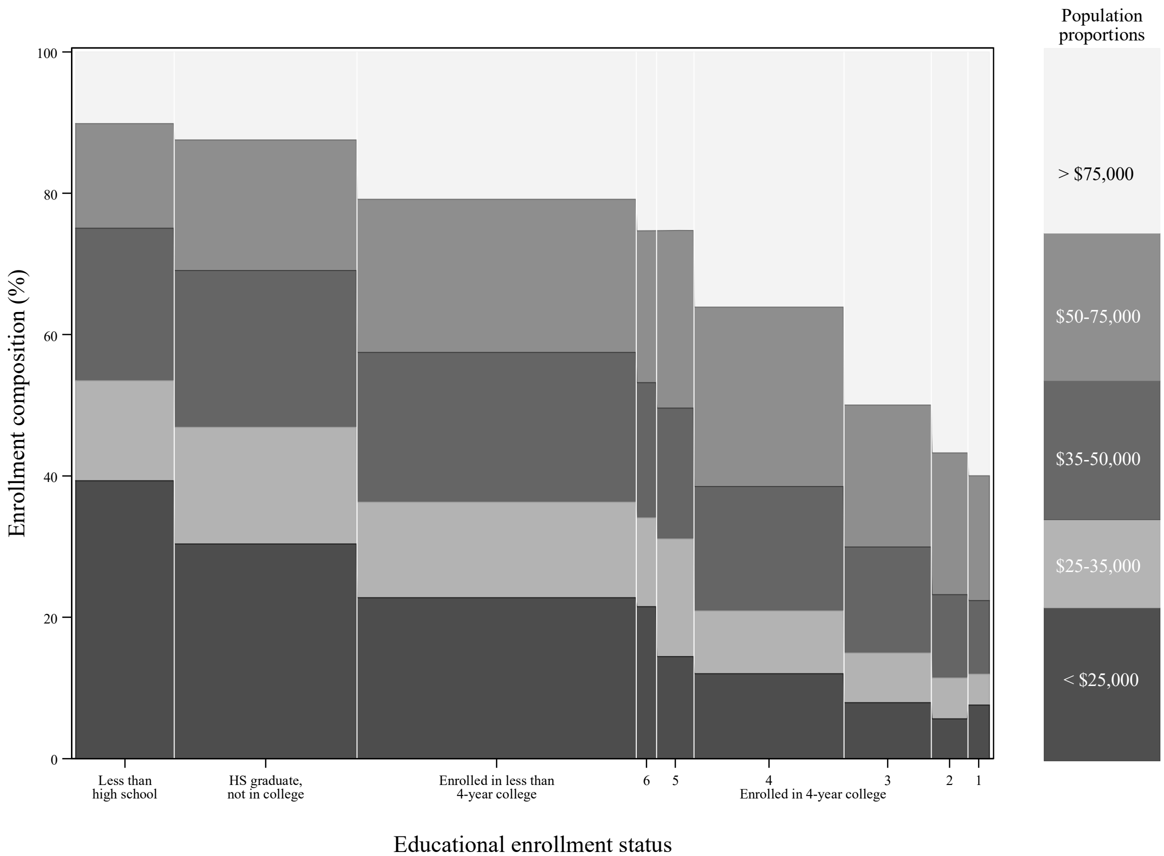
Figure 8. Mean achievement and proportion minority by the number of schools using affirmative action.



Notes. The figure gives the results of the scenario where moderate race- and socioeconomic -based affirmative action policies are used. Arrows start at a schools position in year 15 when it was not using affirmative action, and end at the school's position in year 30. The left-most arrow captures students who do not enroll in college in our simulation. Source: authors' simulation.

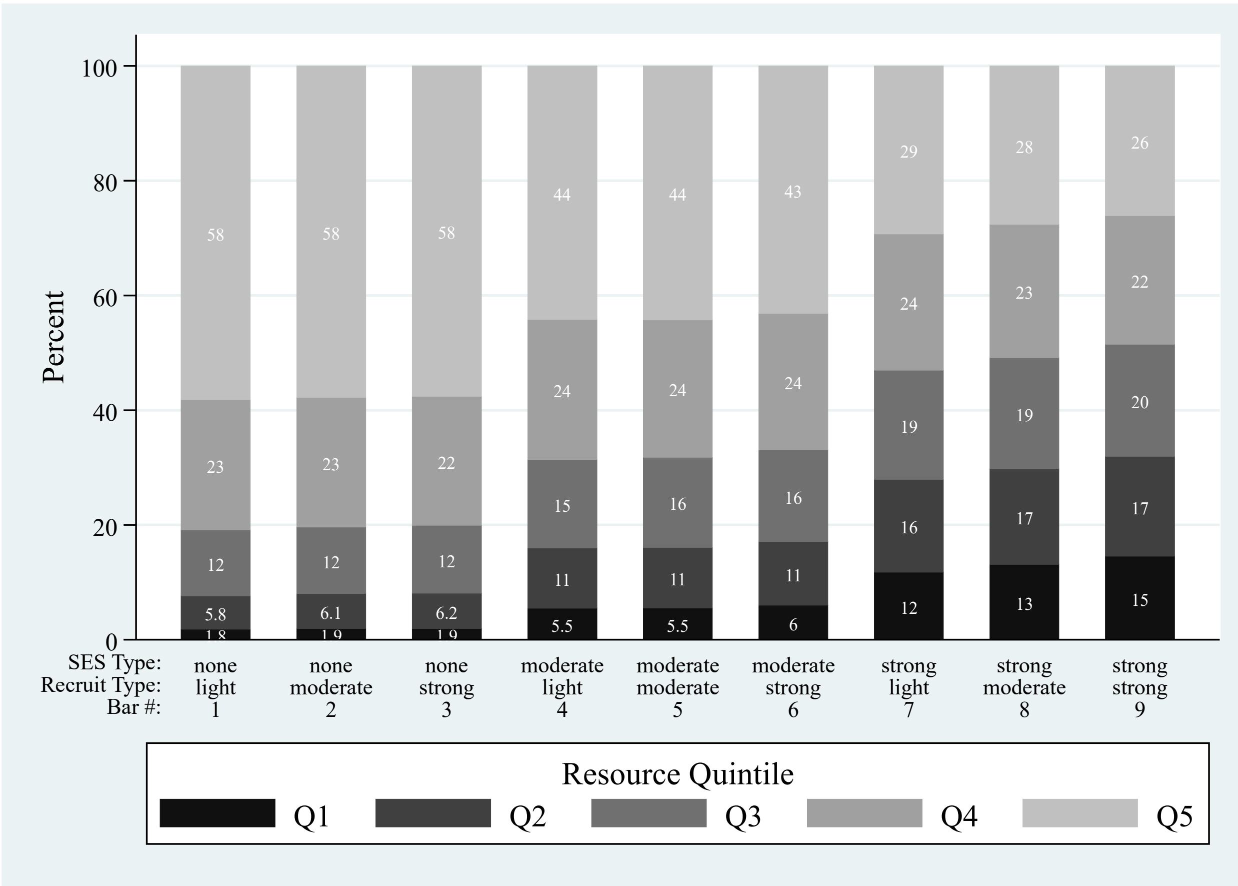
APPENDIX A. SOCIOECONOMIC COMPOSITION OF REAL-WORLD AND SIMULATED COLLEGES

Figure A1: Income Composition of Postsecondary Destinations, Class of 2004



Notes: Figure shows the postsecondary enrollment status of members of the high school class of 2004 by family income and type of college or university. The width of each bar represents the percentage of the college-age population enrolled in different types of colleges and universities (or not enrolled in any college, in the case of the leftmost bars); the vertical dimension describes the income composition of students enrolled in each type of postsecondary institution. Source: Educational Longitudinal Study, 2002.

Figure A2: The socioeconomic composition of colleges using SES-based affirmative action and race-based recruitment, by affirmative action and recruitment strength.



Notes. Moderate and strong SES-based affirmative action scenarios utilize a .375 and .75 weight, respectively, equivalent to 75 and 150 achievement points. Recruitment weights are: light, 50 points; moderate, 100 points; strong, 200 points. SES is socioeconomic status. Source: authors' simulation.

APPENDIX B. ESTIMATES OF THE RELATIVE ADMISSIONS WEIGHT GIVEN TO RACE, SOCIOECONOMIC STATUS (SES), AND ACADEMIC PERFORMANCE

In this appendix we examine past efforts to estimate the relative weights given to race, SES, and academic performance in selective college admissions processes and provide more details on our own analyses. The existing methods for calculating relative admissions weights given to applicants' race, and the weights these results yield, are variable and sometimes misleading. For example, simply comparing the average academic records (such as GPAs or SAT® scores) of students of different races enrolled at selective colleges can be misleading for a number of reasons. First, because of racial disparities in grades and test score distributions, we would expect the mean scores of admitted Black and White students to be different even if a college admitted solely on the basis of test scores.[7] Second, this approach cannot disentangle differences in average scores that are due to differential admission criteria from differences in scores that are due to racial differences in application or enrollment patterns.

A better approach to estimating average affirmative action weights is to use data on a pool of applicants to one or more selective colleges and to estimate the relationship between race/SES and the probability of admissions. This approach was taken by Kane (1998) and Espenshade and Radford (2009). The idea of this approach is to predict admission on the basis of race, academic, and other observable factors and then compare the coefficients on the race variables with the coefficient on SAT® scores. Both Kane and Espenshade and Radford estimated the implicit weight given to race (being Black, specifically, in their models) in the admission process at selective colleges as roughly equivalent to the weight given to an additional 300−400 SAT® points (as measured on the 1600 point SAT® scale that was in use at the time).

[7] This may seem counterintuitive, but it results from the fact that racial differences in mean test scores mean that there are more minority students with very low scores and more White students with very high scores. If a college simply admitted every student with an SAT® score above, say, 1200, the mean score for White students in this group would be higher than that of minority students because of the higher proportion of White students with very high scores.

It is important to note that these estimates apply only to the most selective colleges and universities. Espenshade and Radford's (2009) data set contained only seven selective, 4-year colleges or universities. Kane's (1998) data set came from an analysis of the top 20 percent of 4-year colleges in terms of selectivity. His models based on all 4-year colleges yield estimated weights one-third as large. Such findings are in keeping with the patterns in Figure 1 that suggest there is greater use of race-based affirmative action at the most selective colleges.

Even taking into account the fact that they are based on a limited set of colleges, the Kane (1998) and Espenshade and Radford (2009) SAT-equivalent weight estimates are likely too high. Their models include a number of control variables, such as high school GPA and extracurricular involvement. Because these variables are positively correlated with SAT® scores, their inclusion in the model will tend to attenuate the coefficient on the SAT® score variable. This, in turn, will exaggerate the SAT-equivalent weight (because it is a ratio of the coefficient on race to the coefficient on SAT® scores). Another way to see this is to realize that two students who differ by 300−400 SAT® score points will tend to differ also on many other factors that affect college admission, so the average difference in admission probabilities between two students who differ by 300−400 SAT® points will be much larger than that implied by the SAT® coefficient alone. This means that a smaller difference in SAT® points (along with the other differences in correlated characteristics) will yield an average difference in admission probability equal to that implied by the race coefficient.

Because of these concerns, and because existing estimates do not describe the weight that colleges give to Hispanic students or to low-SES students, we conducted our own simple analysis of recent college admission data. Using data from the 2002 ELS, we estimated racial and SES admissions weights using methods similar to those of Espenshade and Radford (2009) and Kane (1998). We fit a much more parsimonious models than they do, however: we predict the probability of admission using only test scores and dummy variables for race or a standardized variable for SES.[8] To account for the possibility that the implicit weights vary in magnitude along with the selectivity of the college, we repeated this analysis for admission to each of the six Barron's Selectivity categories.

Similar to Kane (1998), we find notable racial admissions preferences only in the top Barron's category, which represents approximately 10 percent of 4-year colleges that are not open admission. We estimate significant positive admissions preferences for both Black and Hispanic students applying to these most selective colleges. We estimate that Black and Hispanic students are given an implicit weight that is roughly equivalent to that given to students with a test score roughly 1.3 standard deviations higher than another student. We find very little or no evidence of racial preferences in admissions to colleges in lower selectivity tiers (for details, see Table B1).

We conducted a similar analysis to estimate the average implicit weight given to low-SES students in admissions. Here we find evidence of slight SES-based affirmative action in the most selective colleges (the weight given to a standard deviation difference in family SES is roughly the same as given to a 0.15 standard deviation test score difference). Moreover, the evidence indicates that students applying to less selective colleges were penalized for their lower SES in the admission process (in these colleges higher SES students were given implicit preference in admissions). The SES weights are, however, relatively small in all cases (for details, see Table B2).

In sum, it appears that, in 2004, affirmative action or other related policies at the most selective colleges increased the probability of minority students' admission substantially by an amount that may

[8] In these analyses, we use SAT® scores, which are reported in the ELS data, as a standardized test score measure. We use them because they are widely observable to colleges (unlike the tests administered as part of the ELS study) and they are standardized on a common scale (unlike GPA). Although colleges of course have access to other information about students when making admissions decisions, we use a single standardized test score measure as a unidimensional proxy for students' academic performance so that we can roughly quantify the implicit weights given to race or SES in college admissions. The weights we estimate therefore should be understood as designed solely to provide information about the rough order of magnitude of the weights given to academic performance, race, and SES in admissions processes. They are not particularly useful as estimates of actual admissions processes.

be as high as the difference between students whose academic records differ by over a standard deviation. SES-based affirmative action policies, however, appear to have been much less prevalent. On average, low-SES applicants appear to have received little or no admissions preference at most colleges.

Table B1. Estimates of Implicit Weight Given to Minority Students in Admissions Process, High School Class of 2004

	All schools	Barrons 4	Barrons 3	Barrons 2	Barrons 1
SAT®	0.076***	0.079***	0.09***	0.093***	0.115***
	(0.002)	(0.003)	(0.003)	(0.005)	(0.006)
Asian	-0.004	-0.028	0.026	0.006	0.007
	(0.011)	(0.022)	(0.021)	(0.029)	(0.024)
	-5.26	*-35.44*	*28.89*	*6.45*	*6.09*
Black	-0.04***	-0.098***	-0.044*	-0.028	0.303***
	(0.010)	(0.016)	(0.021)	(0.034)	(0.040)
	-52.63	*-124.05*	*-48.89*	*-30.11*	*263.48*
Hispanic	0.024*	-0.025	0.01	0.037	0.294***
	(0.010)	(0.018)	(0.021)	(0.031)	(0.034)
	31.58	*-31.65*	*11.11*	*39.79*	*255.65*
Intercept	-0.015	0.038	-0.197	-0.376	-1.102
	(0.019)	(0.033)	(0.038)	(0.061)	(0.080)
N	23,000	6,700	5,000	2,800	2,700

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: Authors' calculations from ELS 2002 study. Standard errors are adjusted for clustering. Estimates are from a linear probability model predicting acceptance to a given selectivity of school as a function of SAT® score and dummy variables for race. SAT® scores are divide by 100. Sample sizes have been rounded to the nearest 100. The implicit admissions weight (in SAT® points) is included in italics below the standard error for each model.

Table B2. Implicit Weight Given to Socioeconomic Status (SES) in Admissions Process, High School Class of 2004

	All schools	Barrons 4	Barrons 3	Barrons 2	Barrons 1
SAT®	0.076***	0.083***	0.092***	0.094***	0.09***
	(0.002)	(0.003)	(0.003)	(0.005)	(0.006)
SES	0.01*	0.027***	0.003	0.001	-0.033*
	(0.004)	(0.007)	(0.008)	(0.013)	(0.014)
	13.2	*32.5*	*3.2*	*1.1*	*-36.6*
Intercept	-0.025	-0.026	-0.216	-0.381	-0.716
	(0.017)	(0.030)	(0.035)	(0.057)	(0.073)
N	23,000	6,700	5,000	2,800	2,700

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: Authors' calculations from ELS 2002 study. Standard errors are adjusted for clustering. Estimates are from a linear probability model predicting acceptance to a given selectivity of school as a function of SAT® score and the ELS SES variable (continuous and standardized). SAT® scores are divide by 100. Sample sizes have been rounded to the nearest 100. The implicit admissions weight (in SAT® points) is included in italics below the standard error for each model.

APPENDIX C. DETAILED EXPLANATION OF AGENT-BASED MODEL

Initialization

For each scenario of the model, we generate *J* colleges with *m* available seats per year (for the sake of simplicity, *m* is constant across colleges). During each year of the model run, a new cohort of *N* students engages in the college application process. Initial college quality (*Q*) is normally distributed, as are race-specific distributions of student achievement (*A*) and student resources (*R*). We allow for race-specific correlations between *A* and *R*. The values used for these parameters, and their sources, are specified in Table 1. We select these values to balance computational speed and distribution density (e.g., for number of colleges and students), real-world data (e.g., for achievement and resource distributions), and based on the original version of the model (ELS 2002; Reardon et al., 2016).

Submodels

Application. During this stage of our model, students generate an application portfolio, with each student selecting n_s colleges to which they will apply. Every student observes each college's quality (Q_c) with some amount of uncertainty (u_{cs}), which represents both imperfect information and idiosyncratic preferences.

$$Q_{cs}^{*} = Q_c + u_{cs};\ u_{cs} \sim N(0, \tau_s). \tag{C.1}$$

The error in students' perceptions of college quality has a variance that depends on a students' resources; students from high-resources families have better information about college quality. Specifically,

$$\tau_s = \mathrm{Var}(Q_c)\left(\frac{1-\rho_s^Q}{\rho_s^Q}\right), \tag{C.2}$$

where ρ_s^Q, the reliability of student perceptions of college quality, is a function of student resources and bounded between 0.5 and 0.7, as described in Table 1.

Students then use perceived college quality (Q_{cs}^*) to evaluate the potential utility of their own attendance at that college (U_{cs}^*), based on how much utility they place on college quality:

$$U_{cs}^* = a_s + b_s(Q_{cs}^*), \tag{C.3}$$

where a_s is the intercept of a linear utility function and b_s is the slope. Reardon et al. (2016) showed that allowing a_s and b_s to vary with students' socioeconomic resources had little effect on college application decisions; as a result we fix both to be constant across students, as described in Table 1.

When present in a given simulation run, race-based recruitment policies (like affirmative action policies) are activated in the appropriate colleges after year 15 of model runs, allowing college quality and enrollment behavior (i.e. colleges' enrollment yields) to stabilize first. At this point, colleges' binary recruitment statuses (S_c)—which had previously all been 0—are set based on model parameters that determine which schools will use recruitment (e.g. the top 4 colleges) and remain constant through the remainder of the model run. Utility is then calculated using model-specific recruitment magnitude values (L):

$$U_{cs}^* = a_s + b_s(Q_{cs}^*) + R_{sc}.$$

Students may augment their own achievement, and they perceive their own achievement with noise. Thus, their assessment of their achievement, for purposes of deciding where to apply, is

$$A_s^* = A_s + \alpha_s + e_s;\ e_s \sim N(0, \sigma_s), \tag{C.4}$$

where α_s represents enhancements to perceived achievement that are unrelated to achievement itself (e.g., strategic extracurricular activity participation or application essay consultation) and e_s represents a student's error in his or her perception of his or her own achievement. The values that are used for these parameters and their relationships with student resources are listed in Table 1. As above, the error in a student's assessment of his or her own achievement has a variance that depends on his or her family resources:

$$\sigma_s = \text{Var}(A)\left(\frac{1-\rho_s^A}{\rho_s^A}\right),$$

(C.5)

where ρ_s^A, the reliability of student perceptions of their own achievement, is a function of student resources and bounded between 0.5 and 0.7, as described in Table 1.[9]

Based on their noisy observations of their own achievement and college quality, students estimate their probabilities of admission into each college:

$$P_{cs} = f(A_s^* - Q_{cs}^*),$$

(C.6)

where f is a function based on admission patterns over the prior 5 years. In each year f is estimated by fitting a logit model predicting the observed admissions decisions using the difference between (true) student achievement and college quality for each submitted application over the past 5 years. We set the intercept to 0 and the slope to $\beta = -0.015$ for the first 5 years of our simulation (since there are no prior estimates to use). These values were selected based on observing the admission probability function over a number of model runs; the starting values do not influence the model end-state, but do influence how quickly the function (and the model itself) stabilizes.

[9] The intercept value, minima, maxima, and linear relationships with resources used for the reliabilities with which students perceive their own achievement and college quality, as well as the intercept and slope values used for students' evaluation of the utility of attending colleges, are based on those used in previous work (Reardon et al., 2016). Briefly, the resource relationships are based on experimentation into the role of differential information quality in the observed sorting of students into colleges by SES (Reardon et al., 2016). In the absence of available empirical evidence, the other values used are plausible estimates: The average student has moderately high, but not perfect, perception of college quality (e.g., familiarity with college rankings) as well as his or her own achievement (e.g., knowledge of their SAT® scores); because of resource, effort, and opportunity costs the utility of attending a very low-quality college is less than 0 (i.e., lower than not attending college). Extensive model testing suggests that our selections of these specific parameter values did not affect the overall interpretation of our results.

Each student applies to a set of n_s colleges, where n_s is determined by the student's resources, as described in Table 1. Given n_s, a student applies to the set of n_s colleges that maximize his or her overall expected utility. To determine the expected utility of an application portfolio, we do the following. Let $E_s^*\{C_1, C_2, \dots, C_{n_s}\}$ indicate student *s*'s expected utility of applying to the set of n_s colleges $\{C_1, C_2, \dots, C_{n_s}\}$, where the colleges in the set are ordered from highest to lowest perceived utility to student s: $U_{C_1 s}^* \geq U_{C_2 s}^* \geq \cdots \geq U_{C_n s}^*$. Define $E_s^*\{\emptyset\} = 0$. Let P_{cs}^* indicate student *s*'s perceived probability of admission to college *c*. Then the expected utility of applying to a given set of colleges is computed recursively as

$$E_s^*\{C_1, C_2, \dots, C_{n_s}\} = P_{C_1 s}^* \cdot U_{C_1 s}^* + \left(1 - P_{C_1 s}^*\right) \cdot E_s^*\{C_2, \dots, C_{n_s}\}. \tag{C.7}$$

In our model, each student applies to the set of colleges $\{C_1, C_2, \dots, C_{n_s}\}$ that maximizes $E_s^*\{C_1, C_2, \dots, C_{n_s}\}$. In principle, this means that a student agent in the model computes the expected utility associated with applying to every possible combination of three colleges in the model and then chooses the set that maximizes this expected utility. The model developed by Reardon et al. (2016) uses a fast algorithm for this maximization; we use the same algorithm here.

Although the model assumes all students are rational, utility-maximizing agents with enormous computational capacity, this is moderated by the fact that the student agents in the model have both imperfect information and idiosyncratic preferences, both of which are partly associated with their family resources. This means that there is considerable variability in student application portfolios, even conditional on having the same true academic records, and that high-resource students choose, on average, more optimal application portfolios than lower-resource students. Both of these features mimic aspects of actual students' empirical application decisions (e.g., Hoxby & Avery, 2012). More generally, the assumption of rational behavior is an abstraction that facilitates focus on the elements of college sorting that we wish to explore. We recognize that real-world students use many different strategies to determine where they apply.

Admission. Colleges observe the apparent achievement ($A_s + \alpha_s$) of applicants with some amount of noise (like the noise with which students view college quality, this also reflects both imperfect information as well as idiosyncratic preferences):

$$A_{cs}^{**} = A_s + \alpha_s + w_{cs};\ w_{cs} \sim N(0, \Phi). \tag{C.8}$$

As described in Table 1, colleges assess students' achievement with a reliability of 0.8. Given that true achievement has a variance of 200^2 in the population, this implies that the error variance colleges' assessments of student achievement is

$$\phi = \mathrm{Var}(A)\left(\frac{1-0.8}{0.8}\right) = .25 \cdot 200^2 = 100^2. \tag{C.9}$$

Thus, in the model, colleges' uncertainty and idiosyncratic preferences have the effect of adding noise with a standard deviation of 100 points (half a standard deviation of achievement) to each student's application.[10]

When present in a given simulation run, affirmative action policies (like recruitment policies) are activated in the appropriate colleges after year 15 of model runs, allowing college quality and enrollment behavior (i.e. colleges' enrollment yields) to stabilize first. At this point, colleges' binary affirmative action statuses (T_c) —which had previously all been 0—are set based on model parameters that determine which schools will use affirmative action (e.g. the top 4 colleges) and remain constant through the

[10] As with the parameter values that describe student perception, the means, minima, and maxima used for the reliability with which colleges perceive student achievement is based on what was used in previous work (Reardon et al., 2016). Although there is a lack of extant empirical evidence to inform these values, we made estimates that seem sensible: collectively, college admission officers have quite a bit of experience evaluating students and thus colleges have a highly accurate (but also not perfect) perception of student achievement. Extensive model testing suggests that our selections of these specific parameter values did not affect the overall interpretation of our results.

remainder of the model run. Perceived student achievement adjusted by model-specific race affirmative action (G) and resource affirmative action (H) magnitude values is given by:

$$A_{cs}^{***} = A_{cs}^{**} + T_c[G \cdot (Black_s|Hispanic_s) + H \cdot R_s].$$

(C.10)

Colleges rank applicants according to A_{cs}^{***} and admit the top applicants. In the first year of our model run, college's expected yield (the proportion of admitted students that a college expects to enroll) is given by:

$$Yield_c = 0.2 + 0.6(College\ quality\ percentile),$$

(C.11)

with the lowest-quality college expecting slightly over 20 percent of admitted students to enroll and the highest quality college expecting 80 percent of admitted students to enroll. In subsequent years, colleges admit $m/Yield_c$ students in order to try to fill m seats (where $m = 150$ in our model). After the first year of a model run, colleges are able to use up to 3 years of enrollment history to determine their expected yield, with $Yield_c$ representing a running average of the most recent enrollment yield for each college.

Enrollment. Students enroll in the college with the highest estimated utility of attendance (U_{cs}^{*}) to which they were admitted.

Iteration. Colleges' quality values (Q_c) are updated based on the incoming class of enrolled students before the next year's cohort of students begins the application process:

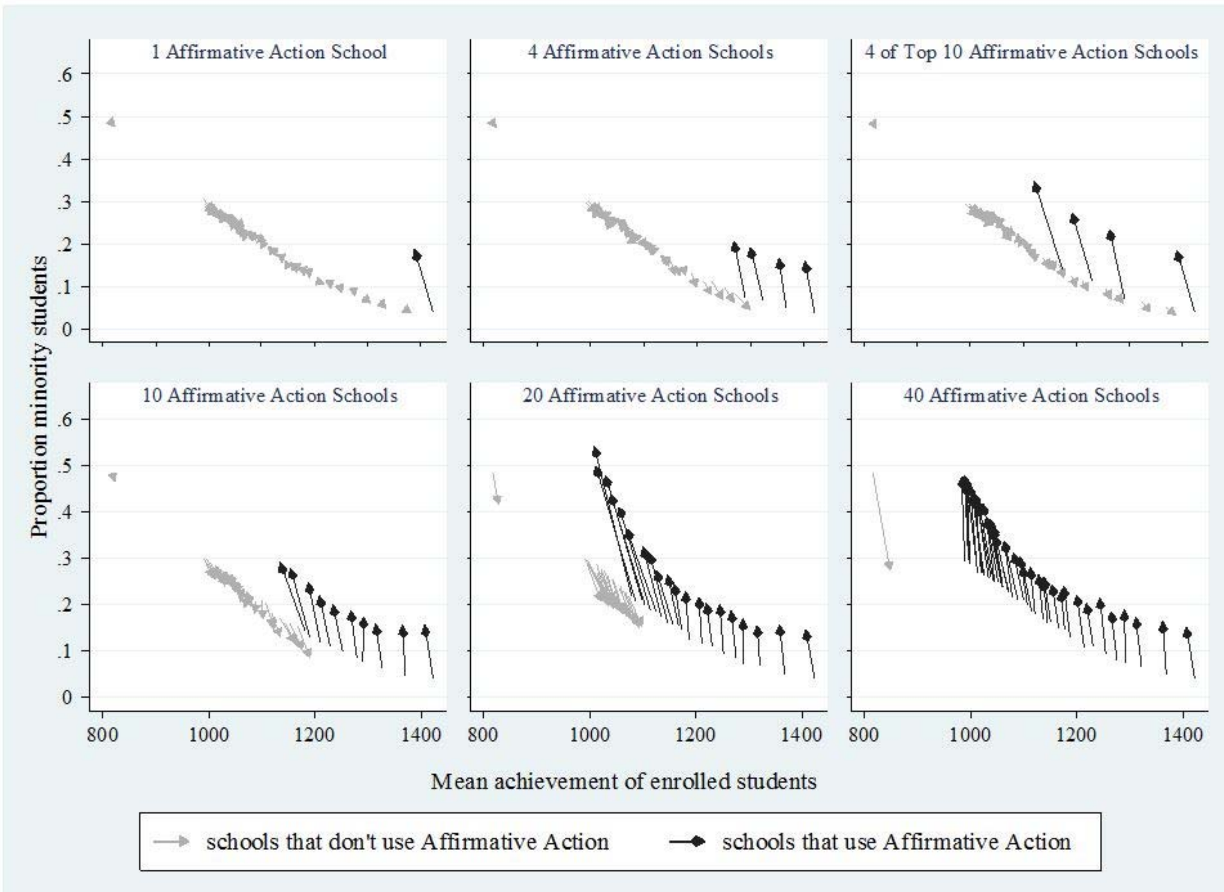
$$Q_c' = 0.9(Q_c) + 0.1(\bar{A}_c),$$

(C.12)

where $\bar{A}_c$ is the average value of A_s among the newest cohort of students enrolled in college c. We run the model for 30 years. In our simulations, this is a sufficient length of time for the models to reach a relatively stable state.

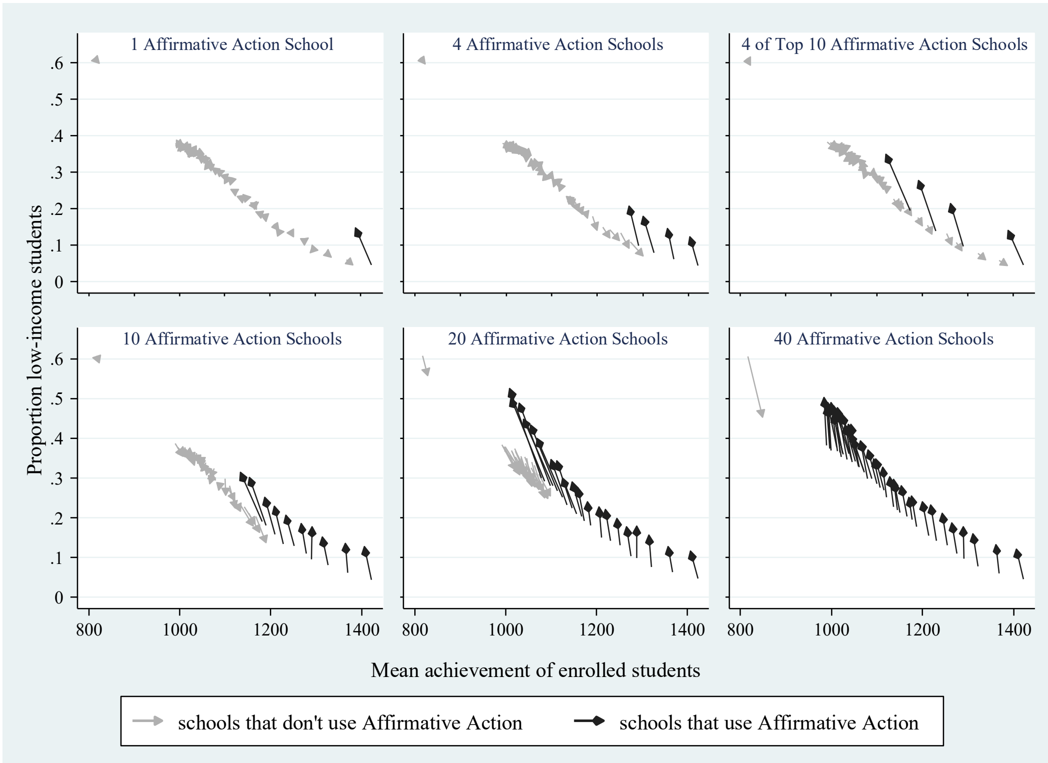
APPENDIX D. Effects of Affirmative Action Policies on Non-AA Schools

Figure D1. The mean achievement and proportion minority by number of schools using affirmative action.



Notes. The figure gives the results of the scenario where moderate race- and socioeconomic -based affirmative action policies are used. Arrows start at a schools position in year 15 when it was not using affirmative action, and end at the school's position in year 30. The left-most arrow captures students who do not enroll in college in our simulation. SES is socioeconomic status. Source: authors' simulation.

Figure D2. The mean achievement and proportion low-income by number of schools using affirmative action.



Notes. The figure gives the results of the scenario where moderate race- and socioeconomic-based affirmative action policies are used. Arrows start at a schools position in year 15 when it was not using affirmative action, and end at the school's position in year 30. The left-most arrow captures students who do not enroll in college in our simulation. Source: authors' simulation.