What Happens After Enrollment? An Analysis of the Time Path of Racial Differences in GPA and Major Choice*

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Abstract

If affirmative action results in minority students at elite schools having much potential but weak preparation, then we may expect minority students to start off behind their majority counterparts and then catch up over time. Indeed, at the private university we analyze, the gap between white and black grade point averages falls by half between the students' freshmen and senior year. However, this convergence masks two effects. First, the variance of grades given falls across time. Hence, shrinkage in the level of the gap may not imply shrinkage in the class rank gap. Second, grading standards differ across courses in different majors. We show that controlling for these two features virtually eliminates any convergence of black/white grades. In fact, black/white gpa convergence is symptomatic of dramatic shifts by blacks from initial interest in the natural sciences, engineering, and economics to majors in the humanities and social sciences. We show that natural science, engineering, and economics courses are more difficult, associated with higher study times, and have harsher grading standards; all of which translate into students with weaker academic backgrounds being less likely to choose these majors. Indeed, we show that accounting for academic background can fully account for differences in switching behaviors across blacks and whites.

Keywords: Grade Inflation, Affirmative Action, Major Choice

JEL Classification Codes: I2, I20, I23

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1 Introduction

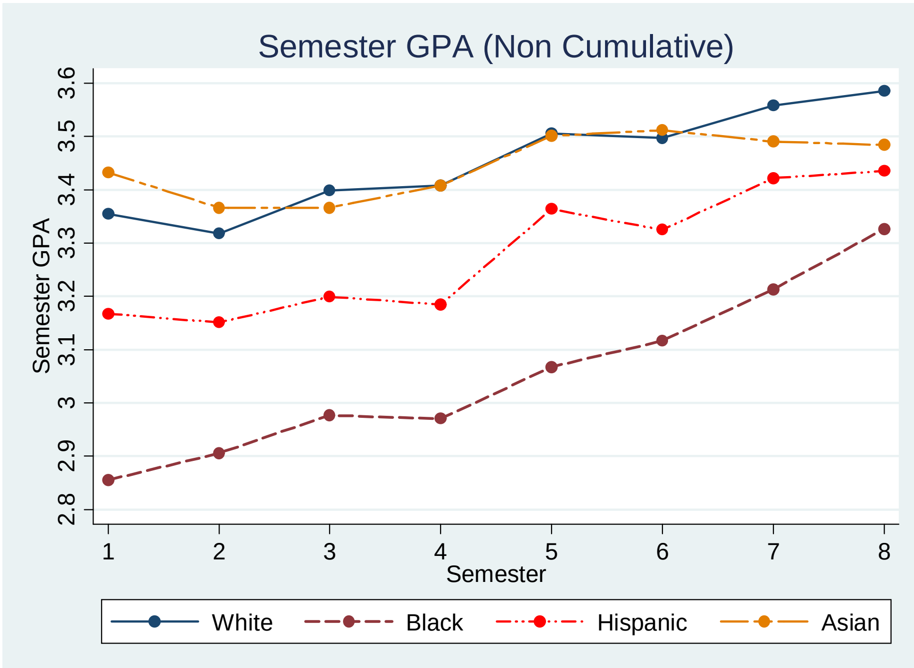
Scholars have known since the Coleman Report in 1966 that the black white educational achievement gap is a robust empirical regularity. Since then, a prolific literature in economics has emerged trying to describe the evolution, causes and consequences of the racial test scores gap in primary and secondary schools. The main findings indicate that African American children enter kindergarten lagging behind their white counterparts, and these differences are likely to persist for the foreseeable future (Neal 2006). Cunha et al. (2006) argue that schooling raises measured ability, but does not close gaps between children from different racial and economic strata, and if anything widens them. Fryer and Levitt (2006), using the Early Childhood Longitudinal Study database, find that by the end of first grade, black children lost the equivalent of almost three months of schooling relative to whites. These trends continue through middle school with both Phillips and Chin (2004) and Hanushek and Rivkin (2006, 2009) documenting increases in the math achievement gap between blacks and whites through the eighth grade.

The divergence in black/white outcomes at early ages is not surprising given disparities in resources between black and white families. However, given similar environments, we may expect blacks to, at least partially, catch up to whites. Indeed, this is one of the potential benefits of affirmative action in higher education: by taking students whose academic background is weak, but whose academic potential is strong, we may expect these students to perform poorly at first as they acquire the needed skills to succeed and then, with time, catch up. By way of illustration, consider the case of Ph.D. economics programs in the United States. International students, who often have Master's degrees upon entry, typically come in better prepared than their American counterparts, with the Americans gradually catching up over time. With affirmative action promoting access to those who are otherwise less prepared, we might expect the beneficiaries of affirmative action to also catch up, at least partially, over the course of their college career.

In this paper, we address the issue of whether black college students catch up to their white counterparts, focusing in particular on students at Duke University. While researchers have documented lower grades for black students in college (see, for example, Betts and Morell 1999), this is to be expected given differences in college preparation. Here, we are interested in whether there is any evidence of blacks catching up to whites. Clearly using data from one highly-selective school may lead to questions about how the results carry over to other environments. Weighed against this, however, is the ability to use within-school variation, ensuring that our results our not driven by grading patterns being different across the different types of schools blacks and whites attend.

An initial glance at data from consecutive cohorts of students who first enrolled in 2001 and

Figure 1: Evolution of students noncumulative semester GPA open by race at Duke University. Source: CLL



2002 suggests that this catch up does occur. Namely, black students who completed college[1] start out significantly behind their white counterparts in terms of grade point average but rapidly catch up. Figure 1 shows that differences in grades between black and white students during their first semester were almost half a grade. However, this disparity was reduced by almost fifty percent by the last semester of college.

There are, however, at least two reasons to be skeptical of Figure 1: variance and course selection. With regard to variance, instructors use much less of the grade distribution in upper year courses[2]. Indeed, the standard deviation of grades for second-semester seniors is 86% percent of the standard deviation of grades for first-semester freshmen. For convergence to occur, it is therefore important to examine differences in class rank over time rather than GPA levels.

The second concern is course selection. Grading standards differ wildly across majors at Duke (see Johnson 1997, 2003), with similar differences seen across many universities (see Sabot and

[1] Graduation rates are quite high at Duke University, with 96% of the students finishing their studies.

[2] Grove et al (2004) show similar trends in grades for a large private university in the northeast. Moreover, data of four years college graduates from the NLSY97 also shows that students GPA increase in upper years of college while their standard deviation decreases. More specifically, mean GPA increased from 3.18 to 3.33, while their standard deviation decreased form 0.574 to 0.481 between the freshman and senior years.

Wakeman-Linn 1991, Grove and Wasserman 2004, Bar et al. 2011 and Koedel 2011).[3] In particular, natural science, engineering, and economics classes have average grades that are 8% lower than the average grades in humanities and social science classes. Note that these averages do not take into account selection into courses: average SAT scores of natural science, engineering, and economic majors are over 50 points higher than their humanities and social science counterparts. Although blacks and whites initially have similar interests regarding whether to major in the more strictly graded fields, the patterns of switching result in 68% of blacks choosing humanities and social science majors compared to less than 55% of whites[4]. We show that accounting for these two issues can explain virtually all the convergence of black white grades.

Accounting for shrinking grade variances and course selection also explains the convergence in grades for a group where we would expect catch up to not occur: legacies. Legacies at Duke start out behind their white non-legacy counterparts (though not as far back as blacks) with 65% of the gap[5] removed by the end of the senior year. Similar major-switching patterns occur for legacies as well, with large shifts away from the natural sciences, engineering, and economics towards humanities and social sciences. The different grading standards across courses legacies and blacks take, coupled with the tighter variances on the grade distributions of upper year courses, accounts for their catch up to their white non-legacy counterparts.

The convergence of black/white grades is then a symptom of the lack of representation among blacks in the natural sciences, engineering, and economics. Over 54% of black men who express an initial interest in majoring in the natural sciences, engineering, or economics switch to the humanities or social sciences compared to less than 8% of white men. While the similar numbers for females are less dramatic across races, they are nonetheless large: 33% of white women switch out of the natural sciences, engineering, and economics with 51% of black women switching.

These cross-race differences in switching patterns can be fully explained by differences in academic background. We show that natural science, engineering, and economics courses are more difficult, associated with higher study times, and are more harshly graded than their humanities and social science counterparts. These trends are particularly true for students with weaker acad-

[3] For instance, Koedel (2011) shows that the grades awarded by education departments are substantially higher than the grades awarded by all other academic departments. The classroom level average GPAs in the education departments are 0.5 to 0.8 grade points higher than in other department groups.

[4] The high proportion of students that switch major can be explained by students learning about their ability and preferences in the first few years of college. Stange (2011) finds that uncertainty about college completion and final major is empirically important. Similarly, Stinebrickner and Stinebrickner (2011a) show that students learning about academic matters plays a particularly prominent role in educational decisions.

[5] Based on comparing non-cumulative semester GPA.

emic backgrounds resulting in those with relatively weaker academic backgrounds being much less likely to persist in natural science, engineering, and economics majors.[6]

The lack of minority representation in the sciences is of national interest and much money has been spent on encouraging minorities to enter the sciences. Seymour and Hewitt (2000) point out that the National Science Foundation alone has spent more than $1.5 billion to increase participation of minorities in the sciences, and two programs at the National Institute of Health have invested $675 million in the same endeavor. Affirmative action, however, may be working against these goals. Attempts to increase representation at elite universities through the use of affirmative action may come at a cost of perpetuating under-representation of blacks in the natural sciences and engineering. Namely, the difference in course difficulty and grading standards between the natural sciences, engineering, and economics and their humanities and social sciences counterparts naturally leads the least prepared students away from the sciences.

The rest of the paper is organized as follows. Section 2 describes the data. Section 3 studies the time path of black, white and legacies GPA differences and their sources. An iterative algorithm is implemented to correct student GPA for disparities in grading practices across disciplines and instructors. Section 4 analyzes racial differences in the choice of major. Section 5 concludes.

2 The Campus Life and Learning Project Data (CLL)

The data we analyze come from the Campus Life and Learning Project (CLL). The data was collected from surveys of two consecutive cohorts of Duke University students before college and during the first, second and fourth college years. The target population was defined as all undergraduate students in the Trinity College of Arts & Sciences and the Pratt School of Engineering. The sampling design randomly selected about one third of white students, two thirds of Asian students, one third of bi- and multiracial students and all black and Hispanic students. As a result, the final sample (including both cohorts) consists of 1536 students: 602 white, 290 Asian, 340 black, 237 Hispanic and 67 bi- or multiracial students.

Each cohort was surveyed via mail in the summer before initial enrollment at the university; the questionnaire was completed by 1181 students, a 77% response rate. However, response rates declined in the years following enrollment: in the first year of college 71% of students responded to

[6] Stinebrickner and Stinebrickner (2011b) show that, in Berea College, the proportion of students who reported that math/science is their most likely major is higher than the proportion for any other major. However, by the second semester of the third year in college, the proportion of students who reported that math/science is the most likely major decreased by 45%. In this regard, they highlight the potential importance of policies at younger ages that lead students to enter college better prepared to study math or science.

the survey; in the second year 65% and in the third year 59%.[7] In addition to the information provided by the surveys, the survey asked permission to access their confidential student records. Since the students were given the opportunity to answer yes to this question on each survey, permission was granted at a very high rate: 91% of the sample granted confidential access to their student records. These records include complete college transcripts, major selection, graduation outcomes, test scores (i.e. SAT, ACT), Duke Admission Officers rankings based on high school curriculum, reader rating scores, high school extracurricular activities, and financial aid and support.

Table 1 shows summary statistics conditional on race and conditional on having the rankings of the Duke Admissions Officers. While the overall sample is 49% female, significant differences in the fraction female are present across races. Namely, 71% of the black sample is female. As shown in Aucejo (2011), the large gender imbalance among blacks is not restricted to Duke. Duke students across all races come from advantaged backgrounds, though this is less true for blacks and more true for whites. The vast majority of white students have two college-educated parents with 40% having fathers with a doctorate or a professional degree. The education levels for black parents are also high, with over 65% of mothers and fathers having at least a college education and 21% of fathers having a doctorate or professional degree. At least 30% of students of each race come from families where family income is over $100,000, with the white rate at 60%. Although SAT scores are high for all groups, there are significant differences across races. White and Asian SAT scores are over one standard deviation higher than black SAT scores.

The second set of rows show the Duke Admission Office evaluations which are scaled from 1 to 5. The largest cross-racial gaps are on achievement and curriculum. Two evaluators are given each file and the scores for each of the categories are averaged across evaluators. The largest cross-racial gaps are on achievement and curriculum. Asian students are ranked highest on average in these two categories, followed closely by whites. Among the different races, blacks score on average the worst in all categories but the gap is smaller on personal qualities and letters of recommendation.

3 The time path of black/white GPA differences and their sources

We focus our attention on differences between black and white outcomes. We begin by using the CLL data to examine black and white performance over time. In addition to the information in Table 1, the CLL data provides transcripts for all those who consented to have their administrative records released. Table 2 shows the median GPA by year for both blacks and whites[8]. Consistent

[7] In the appendix we discuss the patterns of non-response and attrition.

[8] Note that the median student for each race is changing by year.

Table 1: Summary Statistics for Selected Variables by Race

	White	Black	Hispanic	Asian
Demographics				
Female	0.475	0.716	0.484	0.457
Mother BA or more	0.839	0.656	0.772	0.774
Mother Doctorate/Professional Degree	0.118	0.112	0.136	0.083
Mother Ed missing	0.057	0.120	0.084	0.072
Father BA or more	0.921	0.688	0.798	0.902
Father Doctorate/Professional Degree	0.401	0.210	0.265	0.388
Father Ed missing	0.057	0.120	0.084	0.072
Family Inc ≤ $50,000	0.082	0.322	0.223	0.162
$50,000<Family Inc≤$100,000	0.159	0.260	0.209	0.211
Family Inc>$100,000	0.613	0.317	0.484	0.550
Family Inc missing	0.146	0.102	0.084	0.077
Private School	0.305	0.228	0.401	0.246
Private School missing	0.052	0.069	0.055	0.088
SAT (Math + Verbal)	1416	1275	1347	1457
	(105)	(105)	(103)	(94)
SAT missing	0.113	0.096	0.100	0.091
Duke Admissions Office Rank				
Achievement	4.246	3.684	4.029	4.571
	(0.885)	(0.849)	(0.805)	(0.636)
Curriculum	4.655	4.302	4.706	4.861
	(0.582)	(0.732)	(0.513)	(0.433)
Essay	3.432	3.138	3.236	3.465
	(0.550)	(0.396)	(0.486)	(0.587)
Personal Qualities	3.470	3.237	3.246	3.427
	(0.584)	(0.455)	(0.462)	(0.594)
Letters of Recommendation	3.804	3.467	3.478	3.918
	(0.633)	(0.584)	(0.527)	(0.552)
Observations	477	215	192	194

Note: Private school is an indicator variable that denotes if a student attended a private or religious high school. Duke admissions office rank variables take values between 1 and 5. The variable SAT also includes ACT scores that were converted to the SAT scale. If the missing SAT values were imputed, the regression results (presented in the following sections of this paper) would not change. The total number of observations is conditional on having information on Duke Admissions Office Rank.

Table 2: Median GPA and Percent A's for Black and White Students by Academic Year

	White		Black	
	GPA	Percent A's	GPA	Percent A's
Year 1	3.38	29.5	2.88	13.2
Year 2	3.45	31.5	3.01	15.2
Year 3	3.59	38.0	3.13	18.7
Year 4	3.64	42.8	3.31	26.6

Note: Only considers students that have grades in each academic year. The total number of whites and blacks is 513 and 250 respectively.

with Figure 1, there is a large initial gap in black/white GPA's that becomes smaller over time.

Table 2 also shows that the fraction of grades given that are A's rises substantially over time for both blacks and whites. Both races see a fifteen percentage point increase in the fraction of A grades given. This censoring has the effect of compressing the actual grade distribution. In addition to censoring, grading practices may vary by course, and black and white students may select courses differently, particularly over time. The next two subsections investigate the importance of censoring and course selection in explaining black/white grade convergence.

3.1 Class Rank Adjustments with No Selection

With the grade distribution becoming more compressed over time, we focus instead on the individual's year-by-year rank within their class. Table 3 shows that the base rank (i.e. without any adjustment) of the median black student is at the 25th percentile while the median white student is at the 60th percentile after their freshmen year. By their senior year, the median black student has improved to the 29th percentile with the median white student slightly falling to the 59th percentile. The gain in rank for the median black student relative to the median white student is then 5.7 percentage points, or about 16 percent of the original difference in rank. GPA levels, however, show larger convergence. Namely, the gap between the median black and white student's GPA fell by 36% from their freshman to their senior year.[9] Hence, while some improvement is evident in class rank, it is small relative to the gains in levels. However, these results do not take into account the differential grading practices across courses that blacks and whites take. A simple adjustment is then to take out the mean grade of each course before calculating class rank. This is

[9] Note that the median student is changing across years.

Table 3: Median Class Rank for Black and White Students Unadjusted and Adjusted for Average Course Grades by Academic Year

	Base Rank			Adjusting for Mean Grade		
	White	Black	Difference	White	Black	Difference
Year 1	0.599	0.246	-0.353	0.607	0.254	-0.353
Year 2	0.606	0.282	-0.324	0.617	0.259	-0.357
Year 3	0.606	0.270	-0.336	0.590	0.258	-0.331
Year 4	0.591	0.294	-0.296	0.615	0.295	-0.320
Gain from						
Year 1 to Year 4	-0.009	0.048	0.057	0.008	0.041	0.033

Note: Only considers students that have grades in each academic year. The total number of whites and blacks is 513 and 250 respectively. "Base Rank" denotes the median class rank. "Adjusting for Mean Grade" denotes the median class rank adjusted by average course grades.

in part the principle behind Cornell's 1996 decision to publish course median grades online.[10] The second set of columns in Table 3 allows to compare class ranks before and after this adjustment. Here we see that the amount of black/white convergence of the median student falls to 3.3 percent, or about 9 percent of the initial differential. Note that this adjustment, however, does not take into account the selection into courses as more able students may be taking classes with less grade inflation. This is the subject of the next subsection.

3.2 Class Rank Adjusted for Selection

Subtracting off the mean grade in the class ignores the sorting that occurs into classes. Namely, after adjusting for the average grade in the class, an individual will expect to receive lower grades in classes where their peers are stronger. We now adjust our measure of class rank for the differential ability sorting that occurs across classes. Let Y_{ijt} denote i's grades in course j at time t. Grades are a function of the course taken, δ_j, and the abilities of the student. We allow student ability to vary over time to take into account the learning occurs over their time at Duke. Indeed, this is the mechanism through which blacks students may catch up to their white counterparts. Denote i's

[10] See Bar et al. (2009) for an analysis of Cornell's program, with Bar et al. (forthcoming) developing a theoretical model of how students change their course-taking behavior in response to programs such as this one.

ability at time t as α_{it}. We assume grades can be decomposed as follows:[11]

$$Y_{ijt} = \begin{cases} \delta_j + \alpha_{it} + \epsilon_{ijt} & \text{if } \delta_j + \alpha_{it} + \epsilon_{ijt} < 4 \\ 4 & \text{otherwise} \end{cases}$$

where ϵ_{ijt} is assumed to be orthogonal to δ_j and α_{it}. Given the composition of class ability, differences in δ_j then reflect differences in grading practices. Given estimates of δ_j, we can purge the grades of inflation by subtracting these estimates off of observed grades and using the purged grades to form a new measure of class rank. This new measure will then provide a clear picture of how black performance changes across years.

There are, however, at least two issues associated with this specification. First, there are many individual and course fixed effects that we need to recover. Second, grades are censored from above and become more censored in later years. In particular, 41% of grades given for seniors are A's. Combining the iterative strategy in Arcidiacono et al. (2011) to handle multiple fixed effects in large state space problems and the Expectations Maximization (EM) algorithm applied to a Tobit in Amemyia (1984), we are able to obtain estimates of the parameters of interest while circumventing the dimensionality and censoring problems. Given the censoring, however, we need to make a distributional assumption on ϵ and we assume that it is distributed $N(0, \sigma)$.

The algorithm begins with an initial guess of the parameters $\left\{\delta_j^{(0)}, \alpha_{it}^{(0)}, \sigma^{(0)}\right\}$. It then iterates on the following steps with the mth iteration given by:

Step 1: Construct pseudo values of Y_{ijt} using:

$$y_{ijt}^{(m)} = I(Y_{ijt} < 4)Y_{ijt} + I(Y_{ijt} = 4)\left(\delta_j^{(m-1)} + \alpha_{it}^{(m)} + \sigma^{(m-1)}\lambda\left[\left(4 - \delta^{(m)} - \alpha_{it}^{(m)}\right)/\sigma^{(m)}\right]\right) \tag{1}$$

where $\lambda\left[\left(4 - \delta^{(m-1)} - \alpha_{it}^{(m-1)}\right)/\sigma^{(m-1)}\right]$ is the inverse Mill's ratio.[12] These pseudo values are then taken from the uncensored distribution given the current parameter estimates.

Step 2: Using $y_{ijt}^{(m)}$ as the dependent variable and initial guesses of the course fixed fixed effect $\delta^{*(0)}$, solve the least squares problem:

$$\left\{\delta^{(m)}, \alpha^{(m)}\right\} = \arg\min_{\delta,\alpha} \sum_{i=1}^{N} \left(y_{ijt}^{(m)} - \delta_j - \alpha_{it}\right)^2 \tag{2}$$

by iterating on the following two steps until convergence, where the nth iteration is given by:

[11] In principle there is a lower bound on grades. In practice, very few F's are given suggesting that censoring at the bottom end of the distribution is not an issue.

[12] The formula of the inverse Mill's ratio is given by $\lambda(\cdot) = \frac{\phi(\cdot)}{1-\Phi(\cdot)}$

1. Calculate $y_{ijt}^{(m)} - \delta_j^{*(n)}$. Take the mean across grades for i at time t to obtain $\alpha_{ijt}^{*(n)}$
2. Calculate $y_{ijt}^{(m)} - \alpha_{ijt}^{*(n)}$. Take the mean across grades for course j to obtain $\delta_j^{*(n+1)}$

The converged values of α_{it}^* and δ_j^* then provide the updates for $\alpha_{it}^{(m)}$ and $\delta_j^{(m)}$. Given uncensored values of the outcome, we would normally be able to apply OLS here. But due to the large number of student and course fixed effects, it is necessary to iterate, with each iteration lowering the sum of squared errors.

Step 3: The last step updates the variance. Define $v_{it}^{(m)}$ as:

$$v_{it}^{(m)} = \sigma^{(m)} + \left(4 - \delta_j^{(m)} - \alpha_{it}^{(m)}\right)\sigma^{(m)}\lambda\left[\left(4 - \delta^{(m)} - \alpha_{it}^{(m)}\right)/\sigma^{(m)}\right] - \left(\sigma^{(m)}\lambda\left[\left(4 - \delta^{(m)} - \alpha_{it}^{(m)}\right)/\sigma^{(m)}\right]\right)^2 \quad (3)$$

where $v_{it}^{(m)}$ provides the expected variance of the individual's outcome given the outcome was truncated. Now, update $\sigma^{(m+1)}$ using:

$$\sigma^{(m)} = N^{-1/2}\left(\sum_{i=1}^{N}\left[\begin{array}{c} I(Y_{ijt} < 4)\left(Y_{ijt} - \delta_j^{(m)} - \alpha_{it}^{(m)}\right)^2 \\ +I(Y_{ijt} = 4)\left(y_{ijt}^{(m)} - \delta_j^{(m)} - \alpha_{it}^{(m)}\right)^2 + I(Y_{ijt} = 4)v_{it}^{(m)} \end{array}\right]\right)^{1/2} \quad (4)$$

By ordering the estimates of the time-specific student effects we obtain a measure of class rank that is purged of grade inflation. Median black and white class ranks under this method are given in Table 4. Class ranks given in Table 4 are roughly similar to those in the last columns of Table 3 with one exception: the class rank for black students in their senior year falls. Comparing differences in median class rank between whites and blacks shows a black catchup of only 0.8 percentage points by their senior year, or slightly over 2% of the original gap. These results suggest that black catchup in raw grades can be virtually fully accounted for by differences in variances of grades across time as well as differences in grading practices across courses that blacks and whites take.

3.3 Robustness Check: Legacies

As a robustness check, we now consider a group where convergence would seem unlikely: legacies. Legacies likely come into college more prepared due to their advantaged backgrounds. Hence, we would expect legacies to perform relatively worse than non-legacies in their senior year compared to their freshmen year. Looking at raw grades, however, reveals evidence of legacies improving their position over time, with legacies starting out 0.17 points behind their white non-legacy counterparts and improving to 0.06 points behind by their last semester of the senior year. Table 5, however, shows this convergence is illusory by repeating the analysis of Tables 3-4 for legacies. The first set

Table 4: Median Class Rank for Black and White Students Adjusting for Course Selection

	White	Black	Difference
Year 1	0.601	0.249	-0.352
Year 2	0.618	0.251	-0.367
Year 3	0.596	0.262	-0.334
Year 4	0.612	0.268	-0.344
Gain from			
Year 1 to Year 4	0.011	0.019	0.008

Note: Only considers students that have grades in each academic year. The total number of whites and blacks is 513 and 250 respectively.

of columns in Table 5 show that legacies gain over 5.5 percentage points relative to their white non-legacy counterparts, making up a third of the initial gap. However, just subtracting off the mean grade before calculating class rank shows instead that legacy position drops over time. Namely, median legacy position relative to their non-legacy counterpart drops by 2.1% from their freshmen year to their senior year. Note that this occurs both because legacies are taking more harshly graded courses as freshmen and because they are taking more leniently graded courses as seniors.

The last set of columns adjust for selection into courses. Selection into courses has no effect on legacy rank as seniors relative to the second set of columns. However, controlling for course selection as freshmen raises legacy rank. The net effect is then a widening of the gap between white non-legacies and legacies over time. While the unadjusted class rank showed the median legacy improving their position relative to the median white non-legacy by 5.5 percentage points, adjusting for selection shows their position actually falls by 3.8 percentage points. Therefore, the fact that raw grades show a convergence pattern between legacies and white non-legacies (which is highly unexpected to occur, as it is confirm in our analysis) indicates that the similar catch up observed for African Americans is not mainly a consequence of highly potential blacks showing a substantial improvement relative to their peers but instead an illusory effect created by course selection and grade compression.

3.4 Which students improve their position?

With blacks showing little evidence of catching up once we account for selection into classes, what groups do improve their position? To answer this question we begin by transforming class ranks such that they are distributed N(0,1). Then, we differenced the transformed class rank

Table 5: Time Path of Median Legacy and White Non-Legacy Class Rank

	Base Rank			Adjusting for Mean Grade			Adjusting for Selection		
	Non-Legacy	Legacy	Difference	Non-Legacy	Legacy	Difference	Non-Legacy	Legacy	Difference
Year 1	0.631	0.480	-0.152	0.636	0.522	-0.114	0.628	0.536	-0.092
Year 2	0.612	0.605	-0.007	0.628	0.573	-0.055	0.628	0.613	-0.014
Year 3	0.628	0.589	-0.039	0.606	0.572	-0.033	0.620	0.561	-0.058
Year 4	0.620	0.523	-0.097	0.639	0.504	-0.135	0.634	0.504	-0.130
Gain from									
Year 1 to Year 4	-0.012	0.043	0.055	0.003	-0.018	-0.021	0.006	-0.032	-0.038

Note: "Base Rank" denotes the median class rank, "Adjusting for Mean Grade" denotes the median class rank but adjusted by average course grades, and "Adjusting for Selection" denotes the median class rank adjusted for course selection. Non-Legacy refers only to white non-legacy.

for seniors with that of freshmen. Finally, we regressed this gain in class rank on a series of characteristics.

Results are presented in Table 6. The first columns just controls for race and gender. Here we see that males and Asians lose ground during their time at Duke relative to their female and non-Asian counterparts. This result continues as more controls are added. The second column adds SAT scores (normalized to be N(0,1)), whether the individual attended a private school, family income, and education levels of the parents. High SAT scores are associated with lower gains, suggesting that Duke is good at identifying students with low SAT scores but who have the potential to catch up their high SAT score counterparts. The one other significant coefficient is on having a mother with a doctoral degree.

The third column of Table 6 adds measures of the Duke ranking of the applicant. Here, we create five dummy variables, one for each of the Duke ranking measures.[13] Being highly ranked on achievement is associated with decreases in class rank as are having relatively strong letters. In contrast, being highly ranked on personal qualities and the essay is associated with gains in class rank. Controlling for Duke rankings renders the SAT score results insignificant[14].

In order to address concerns related to possible lower levels of effort exerted by some individuals in their senior year; the second set of columns of Table 6 repeats the analysis but uses changes between the freshman and junior year. The negative effect on Asians disappears, suggesting that Asian students are particularly prone to decreasing their effort in their senior year. The coefficient on male, while still significant is now half the value. In addition, columns (2-3) and (5-6) show the same patterns on SAT scores and the Duke rankings, suggesting that those with lower SAT scores and exhibiting potential (as opposed to preparation) improve their relative position. Finally, the coefficient on black becomes negative and significant once controls for SAT scores are included. This outcome could be explained by blacks with lower SAT scores not being able to significantly improve their ranking over time, unlike their other low SAT counterparts.

[13]For each ranking category, we created the dummy variables by choosing splits such that a significant fraction received both a high and low ranking. For achievement, recommendations, personal qualities and the essay a high ranking was above 3.5, above 3.75, above 3.7, and above 3.7 respectively. The student needed to receive a 5 to obtain the high ranking on curriculum.

[14]It is important to highlight that the negative coefficient on SAT is not given by a mechanical result (i.e. students at the top of the distribution initially having less room to move up in later years). This result only implies that SAT is more correlated with the freshman class rank than the senior or the sophomore ones.

Table 6: Estimates of Gains in Class Rank

	Senior Rank−Freshman Rank			Junior Rank−Freshman Rank		
	(1)	(2)	(3)	(4)	(5)	(6)
Female	0.228	0.220	0.228	0.122	0.106	0.110
	(0.048)	(0.048)	(0.048)	(0.043)	(0.044)	(0.044)
Black	0.048	-0.026	-0.059	-0.084	-0.165	-0.180
	(0.089)	(0.095)	(0.096)	(0.080)	(0.086)	(0.087)
Hispanic	-0.027	-0.073	-0.067	-0.061	-0.099	-0.097
	(0.087)	(0.088)	(0.089)	(0.078)	(0.080)	(0.080)
Asian	-0.281	-0.239	-0.208	-0.098	-0.060	-0.041
	(0.070)	(0.070)	(0.070)	(0.063)	(0.064)	(0.064)
SAT Score		-0.085	-0.040		-0.092	-0.066
		(0.028)	(0.030)		(0.025)	(0.027)
Mother college		-0.027	-0.027		-0.033	-0.039
		(0.066)	(0.065)		(0.059)	(0.059)
Mother Ph.D.		0.260	0.258		0.175	0.174
		(0.078)	(0.078)		(0.071)	(0.071)
Father college		0.058	0.032		0.053	0.032
		(0.086)	(0.085)		(0.078)	(0.077)
Father Ph.D.		-0.012	0.014		0.061	0.074
		(0.055)	(0.055)		(0.050)	(0.050)
Duke Achievement			-0.200			-0.151
			(0.060)			(0.054)
Duke Curriculum			-0.037			0.010
			(0.055)			(0.050)
Duke Essay			0.040			0.097
			(0.054)			(0.049)
Duke Recommendation			-0.119			-0.096
			(0.054)			(0.049)
Duke Personal Qualities			0.109			0.057
			(0.052)			(0.047)
R^2	0.039	0.067	0.089	0.01	0.035	0.052
Observations				1132		

Note: OLS regressions, dependent variables denote change in transformed class rank. See footnote 13 for an explanation on how the variables Duke Achievement, Curriculum, Essay, Recommendation and Qualities were constructed. Regression results in columns 2, 3, 5 and 6 also include controls for family income and type of high school attended (i.e. public or private). SAT score was normed to $N(0,1)$.

4 Racial Disparities in Major Choice

In the introduction, two post-enrollment trends in black/white educational outcomes were described. First, black students see their grade point averages come closer to their white counterparts as students move from their freshman to senior year. But in the previous section, we showed that this cross-race convergence of grades is driven not by black students catching up, but rather by differences in grading patterns and course selection. We now turn to the second trend, namely that black students are much more likely to leave natural science, engineering, and economics majors than their white counterparts. Next, we present evidence indicating that there are differences in the grading patterns and the demands that courses in different majors place on their students. As a consequence, these differences then lead to students with worse academic backgrounds being more likely to move away from the natural sciences, engineering, and economics majors. Indeed, we show that differences in academic background can fully account for the cross-race disparities in persistence in the natural sciences, engineering, and economics.

4.1 Patterns of major switching by race

Table 7 reports both expected majors and final majors split by race (black and white) and by gender[15]. The probability of choosing natural science, engineering, or economics as a final major is over 12 percentage points higher for whites than for blacks. This difference is in part given by females being more likely to choose humanities and social science majors, together with the fact that over 70% of the black population at Duke belongs to this gender group. However, splitting out the differences by gender also indicates that a portion of the gap is due to differences in choices between black and white males.

More specifically, the proportion of white males choosing natural science, engineering, or economics majors is over 19 percentage points higher than the corresponding proportion of black males. This occurs despite black males showing a much greater initial interest in natural science, engineering, and economics majors, though this result is clouded by white males being more likely to report uncertainty about their future major.[16] White females are also more likely to choose natural science, engineering, or economics majors than black females, but the gap is small. Again, black females express a greater preference for natural science, engineering, and economics majors but are also less likely to report that they are uncertainty about their future major.

[15] The total sample size of this table (which only includes black and white students) is 663.

[16] Uncertainty is captured by individuals responding to the expected major question with "Do not know".

Table 7: Final Major and Expected Major Open by Gender and Race

	White	Black	White Male	Black Male	White Female	Black Female
Final Major (%)						
Humanities/Social Science	55.3	67.9	43	62.8	68.8	69.9
Natural Sci/Engineering/Economics	44.7	32.1	57	37.2	31.2	30.1
Expected Major (%)						
Humanities/Social Science	25.7	30	21.5	16.9	30.2	35.4
Natural Sci/Engineering/Economics	39.8	48.3	47.3	55.9	31.4	45.1
Do not Know	34.5	21.7	31.2	27.2	38.4	19.4

Note: Expected major was reported in the summer previous coming to Duke. "Do not Know" indicates students who reported not knowing their initial major at that time.

Table 8 restricts the sample to those students who reported an expected major[17]. This table shows that blacks are much less likely than their white counterparts to persist in natural science, engineering, and economics majors[18]. While overall the proportion of blacks expressing an initial interest in natural science, engineering, and economics major is almost 1 percentage point higher than the proportion of whites, the final proportion graduation on these fields of studies is over 20 percentage points lower. Among whites, the proportion that start out in natural science, engineering, or economics is 10 percentage points lower than the proportion who finish in these majors, but this is substantially smaller than the rate for blacks. Differences conditional on gender are also stark. Both black males and black females express higher initial interest in natural science, engineering, and economics majors than their white counterparts, yet both show substantially lower proportions choosing natural science, engineering, or economics as final majors. If we condition on the subsample that report an initial major, 76.7% of black males initially choose natural science, engineering, or economics majors but only 35% obtain a degree in one of these majors. For black women, the numbers are less extreme but nonetheless stark: 56% start in economics, engineering, or natural science majors, though only 27.7% has graduated in one of them. In contrast, the differences between initial and finishing proportions in natural science, engineering, and economics are

[17] The proportion of students that reported "Do not know" is 30%.

[18] The National Longitudinal Survey of Freshmen, which follows a cohort of first-time freshman at 28 selective colleges and universities, shows a similar pattern in major persistence.

Table 8: Final Major and Expected Major Open by Gender and Race Conditional on Not Reporting "Do not Know"

	White	Black	White Male	Black Male	White Female	Black Female
Final Major (%)						
Humanities/Social Science	49.5	70.4	36.4	65.0	65.6	72.3
Natural Sci/Engineering/Economics	50.5	29.6	63.6	35.0	34.4	27.7
Expected Major (%)						
Humanities/Social Science	39.2	38.3	31.3	23.3	49	44
Natural Sci/Engineering/Economics	60.8	61.7	68.7	76.7	51	56

Note: Expected major was reported in the summer previous coming to Duke.

5 percentage points and 17 percentage points for white males and white females respectively.

4.2 Differences in Selection and Major Demands

To explain why individuals leave the natural sciences, engineering, and economics as well as the large differences across races, we first examine how this group of majors is different from their humanities and social science counterparts. Three main differences emerge. First, similar to Johnson (1997, 2003), we show that grading practices vary dramatically across these major groupings. Second, those students who are better prepared academically are more likely to persist in the natural sciences and economics. Finally, and perhaps related to the differences in grading practices, students are working harder in natural science and economics classes and perceive these classes to be more challenging than classes in the humanities and social sciences.

For each of the two major categories, we calculated the average grade given across courses by year with the results reported in Table 9[19]. For freshmen, average grades given in humanities and social sciences classes are almost a half grade higher than those in the natural sciences, engineering, and economics class[20]. The gap is even larger among blacks at over 0.7 points. Despite large differences in test scores and lower grades on average, the average grades black freshmen receive in humanities

[19] The total number of grades in humanities/social science for all races (black) considering all years is 23588 (5340) while in natural sci/engineering/economics is 15704 (2530).

[20] Similarly, Bar et al. (forthcoming) shows that humanities courses at the College of Arts and Sciences of an elite university in the United States provide higher grades than natural sciences ones.

Table 9: Average Grades Received by Type of Course and Year

	Humanities/Social Science		Natural Sci/Engineering/Economics	
	All Races	Black	All Races	Black
Freshman	3.45	3.17	3.05	2.40
Sophomore	3.45	3.19	3.17	2.53
Junior	3.52	3.23	3.32	2.72
Senior	3.55	3.32	3.43	3.03

and social science classes are higher than the average grades received by freshmen students of all races in natural sciences, engineering, and economics classes.

The differences in grades across the two groups does become smaller over time, which is in part reflective of selection out of natural science, engineering, and economics. While the rise in average grades across years is small in humanities and social science classes, this is dwarfed by the rise in grades in natural sciences, engineering, and economics classes. The average grade given to seniors in natural science, engineering, and economics classes is almost 0.4 points higher than the average for freshmen. This increase over time is even larger for blacks at over 0.6 points. However, despite this increase in grades over time, for all races on average and for blacks, seniors in natural science, engineering, and economics classes have lower grades on average than freshmen in humanities and social science classes.

These grade differences occur despite natural science, engineering, and economics majors drawing the more academically-prepared students. Table 10 shows average SAT scores broken out by initial and final major. Regardless of the student's initial major, those whose final major is in the humanities or social sciences have on average lower SAT scores than those whose final major is in the natural sciences, engineering, or economics. Indeed, those who begin their studies in natural science, engineering, or economics and then switch to humanities or social science have SAT scores that are on average over 70 points lower than those who persist in natural sciences, engineering, or economics.

Given the different grading practices as well as the sorting across majors, we may also suspect that study times vary across courses taken in these major categories as well. We are then interested in the relationship between number of courses taken in the natural sciences, engineering, and economics category and study time. The CLL survey asked students in both their freshman and sophomore years the following question:

Table 10: Major Migration by Initial Major and SAT

	Final Major			
	Percent of Students		Mean SAT	
Expected Major	Humanities/ Social Science	Nat Sci/Eng/ Economics	Humanities/ Social Science	Nat Sci/Eng/ Economics
All Races				
Humanities/Social Science	22%	2%	1379	1406
Natural Sci/Engineering/Econ	11%	33%	1362	1434
Do not know	21%	11%	1389	1434
Blacks				
Humanities/Social Science	29%	1%	1277	-
Natural Sci/Engineering/Econ	26%	22%	1270	1289
Do not know	13%	9%	1231	1307

Note: The sample size for all races (blacks) is 1090 (203). "Do not Know" indicates students who reported not knowing their initial major. The mean SAT value for black students switching from humanities/social science to natural sci/engineering/econ was not reported in order to protect the identity of the students (i.e. the sample size of this cell is 2). However, we can state that the mean SAT score for this cell is higher than the humanities/social science-expected major and the humanities/social science-final major.

- Since entering college, how much time have you spent during a typical week doing the following activities?

of which "studying/homework" was one of the options. Respondents were given a menu of time intervals as possible answers.[21] Over 20% of observations in both years are censored at the top category, 16 or more hours. We used midpoints for the time intervals except for the last interval and then estimated censored regressions where study time was the dependent variable.

Results are presented in Table 11. The first four columns use freshmen study time as a dependent variable while the second four use sophomore study time. In addition to the number of courses in natural science, engineering, and economics and the total number of courses taken, the first column for each group controls for race as well as gender. Controls are then added for SAT score and the ranking of the applicant by the Duke admissions office[22]. The final column in each group restricts the analysis to those who took a usual course load, in this case eight courses during the academic year.

Table 11 shows that the coefficients on female are always significant and positive, while on races are insignificant in most of the cases. In this regard, the results suggest that females spend around two to two and a half hours more studying a week than their male counterparts[23], with the stronger effects found in the sophomore year. Given that the median study time reported is eight hours a week, this is a substantial difference.

The total number of courses and number of natural science, engineering, and economics courses are scaled to correspond to the number of classes taken in a semester as opposed to the whole year. Switching one humanities or social science class to a natural science, engineering, or economics class is associated with a half-hour to forty-five minute increase in weekly study time.[24] Comparing the coefficient on the number of natural science, engineering, and economics classes to the coefficient on total number of courses suggest that natural science, engineering, and economics courses are associated with 50% more study time that social science and humanities courses[25]. Note that these

[21] The intervals are: 0 hours per week, less than 1 hour, 1 to 5 hours, 11 to 15 hours, 16 or more.

[22] We use the same set of dummy variables as in Table 7.

[23] Stinebrickner and Stinebrickner (2004) find similar results. They show that males study half an hour less per day than females.

[24] Babcock (2010), Babcock and Marks (forthcoming) and Stinebrickner and Stinebrickner (2008) also show large differences in study time across majors. Babcock (2010) provides evidence that harsher grade distributions result are associated with more study time.

[25] If economics were classified as social science, then there would be a slight decrease in the the study time for engineering and natural sciences relative to humanities, social sciences, and economics. However, the coefficient would remain statistically significant.

results should not be interpreted as causal. Rather, we are describing the correlations seen in the data: whether it is selection into the courses or actual work requirements, more studying is occurring in natural science, engineering, and economics classes.

The CLL provides further evidence indicating that classes in the natural sciences, engineering, and economics require more work. Basically, students were asked to name their most challenging course for the fall of their freshmen year as well as the fall of their sophomore year. Table 12 gives the fraction who listed natural science, engineering, or economics courses as their most challenging ones, and given that individuals take different mixes of courses, the probability of choosing a natural science, engineering, or economics course as most challenging if we randomly chose among the courses taken. The ratio of these two numbers is given in the third column.

The third column shows that, in first semester freshmen courses, a natural science, engineering, or economics course will be 46% more likely to be chosen as the most challenging courses than if the most challenging course was randomly assigned. The ratios for females are higher, with the ratios higher still for blacks. As freshmen, blacks are 69% more likely than random to choose a natural science, engineering, or economics course as most challenging. The results for blacks can be partly explained by academic background mattering more in the natural sciences, engineering, or economics. This is shown by those who have SAT scores one standard deviation below the mean also having higher ratios than the average for the population. The gap between humanities and social sciences versus natural science, engineering, and economics classes in terms of which classes are most challenging increases over the first two years of colleges as the ratios for all groups are higher in the sophomore year.

4.3 Explaining Racial Disparities in Switching Behavior

Given differences in grading practices and the demands of different majors, we now see how much of the racial disparity in switching out of natural sciences, engineering, and economics can be explained with observable characteristics. Table 13 presents marginal effects from a logit model of switching out of natural sciences, engineering, or economics.[26] Column (1) controls only for gender and race. Here we see large and positive coefficients on both female and black which is consistent with the results from Table 8. Hispanics are also more likely to switch out while Asians are more likely to persist.

Column (2) controls for SAT score. None of the race coefficients are statistically significant and the coefficients on black and Hispanic are cut by more than half. Those with high SAT scores are

[26] Given that so little switching occurs in the opposite direction (i.e. from humanities or social sciences to natural sciences or economics), we only focus on switches away from natural sciences and economics.

Table 11: Study Time

	Freshmen				Sophomores			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	2.087	2.023	1.914	2.075	2.655	2.679	2.605	2.660
	(0.399)	(0.402)	(0.398)	(0.398)	(0.360)	(0.361)	(0.361)	(0.497)
Number of Nat. Sci./Eng./Econ. Courses	0.494	0.516	0.540	0.736	0.797	0.741	0.764	0.713
	(0.213)	(0.214)	(0.216)	(0.246)	(0.153)	(0.155)	(0.157)	(0.207)
Total Number of Courses	0.904	0.986	0.817		0.577	0.572	0.566	
	(0.544)	(0.546)	(0.544)		(0.341)	(0.341)	(0.340)	
Black	0.123	-0.158	0.226	0.300	0.171	0.489	0.653	0.435
	(0.717)	(0.756)	(0.759)	(0.905)	(0.668)	(0.697)	(0.704)	(0.997)
Hispanic	-0.024	-0.178	0.167	0.313	-0.249	-0.082	0.041	-0.733
	(0.710)	(0.734)	(0.724)	(0.842)	(0.629)	(0.636)	(0.642)	(0.870)
Asian	0.908	0.973	0.875	1.238	0.089	0.006	-0.073	0.666
	(0.550)	(0.553)	(0.550)	(0.646)	(0.516)	(0.518)	(0.518)	(0.698)
SAT	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Duke Rank	No	No	Yes	Yes	No	No	Yes	Yes
Only Typical Load	No	No	No	Yes	No	No	No	Yes
Observations	883	883	883	623	857	857	857	471

Note: Censored regressions, the dependent variable is a discrete measure for study time in freshman (columns 1 to 4) and sophomore (column 5 to 8) years. The variable "Only Typical Load" refers to eight courses per year. "Duke Rank" denotes the Duke admission rank variables (see footnote 13 for an explanation on how these variables were constructed).

Table 12: Most Challenging Course

	Actual	Random	Ratio	Observations
Freshmen				
Overall	0.694	0.474	1.464	786
Female	0.688	0.439	1.567	455
Black	0.758	0.448	1.692	154
SAT one standard deviation below the mean	0.674	0.427	1.578	155
Sophomores				
Overall	0.717	0.453	1.582	706
Female	0.698	0.420	1.662	396
Black	0.761	0.394	1.931	142
SAT one standard deviation below the mean	0.654	0.365	1.791	127

Note: "Actual" indicates the fraction of students (in freshman or sophomore year) who listed natural science, engineering, or economics courses as their most challenging ones. "Random" denotes the probability of choosing a natural science, engineering, or economics course as most challenging if we randomly chose among the courses taken. Finally, "Ratio" indicates "Actual" over "Random" significantly less likely to move out of natural science, engineering, and economics, consistent with Table 10. The next two columns add measures of the ranking of the Duke admission's office as well as the first period student effect from the grades analysis (α_{i1}). Adding more controls further lowers the black coefficient while affirming that those with stronger backgrounds are more likely to persist in the natural sciences, engineering, and economics. Both the first period student effect and having a strong high school curriculum make switching out of the natural sciences, engineering, and economics less likely. Overall, while the gap between males and females persists[27], racial differences can be full explained with observable characteristics[28].

Table 14 repeats the analysis in Table 13 but this time includes those who report that they do not know their expected major. We then add an indicator variable for answering "do not know" to the expected major question. The results mirror those in Table 13. With no controls, both blacks and females are significantly more likely than whites and males to choose humanities and social sciences conditional on not choosing humanities and social sciences initially. Adding controls for academic preparation reduces the black coefficient to zero while maintaining the high probability of choosing humanities or social sciences for women.

To further reenforce the point that the cross-race differences in persistence in natural sciences, engineering, and economics is driven by academic background, we examine data on the reasons individuals switched majors. In particular, the CLL survey asked students during their sophomore year if they had changed their major and, if so, why. Students were given a series of reasons and could check more than one reason for switching. Two of the potential answers relate directly to academic preparation:[29]

- Lack of pre-college academic preparation for the major course requirements
- Academic difficulty in the major course requirements

We categorized an individual as switching because of their academic background if they marked either of the two answers above as a reason they switched majors. Over 30% of individuals who switched majors in their sophomore year did so in part because of their academic background. We

[27] The higher proportion of females relative to males leaving sciences is an empirical regularity that has been analyzed in Carrell et al. (2010). They show that professor gender affects female students' propensity to persist in the sciences.

[28] If (instead) economics is classified as a social science, the coefficient on female and black will fall slightly but they will remain statistically significant.

[29] The other reasons were: 1) *Academic interests and values have changed since arriving at Duke, 2) Career interests have changed since arriving at Duke, 3) Career values have changed since arriving at Duke, 4) Lack of pre-professional learning opportunities available (e.g., internships, research opporutnities*, and 5) *Other.*

Table 13: Logit Marginal Effects on the Probability of Switching Out of the Natural Sciences, Engineering and Economics

	Specification			
	(1)	(2)	(3)	(4)
Female	0.188	0.174	0.179	0.187
	(0.046)	(0.047)	(0.048)	(0.048)
Black	0.251	0.115	0.053	0.019
	(0.067)	(0.072)	(0.070)	(0.064)
Hispanic	0.130	0.055	0.058	0.049
	(0.068)	(0.069)	(0.071)	(0.067)
Asian	-0.100	-0.082	-0.048	-0.042
	(0.048)	(0.049)	(0.052)	(0.051)
SAT Score		-0.092	-0.058	-0.032
		(0.027)	(0.027)	(0.027)
Duke Achievement			-0.091	-0.043
			(0.055)	(0.053)
Duke Curriculum			-0.167	-0.145
			(0.057)	(0.058)
Duke Essay			-0.066	-0.067
			(0.045)	(0.045)
Duke Recommendation			-0.065	-0.037
			(0.046)	(0.044)
Duke Personal Qualities			0.007	0.009
			(0.049)	(0.049)
Year 1 Student Effect				-0.084
				(0.025)
Log likelihood	-239.2	-231.8	-219.9	-213.2
Observations		499		

Note: See Table 1 for a description of the Duke admission's office variables. "Year 1 Student Effect" refers to the first period student effect (α_{i1}) from the grades analysis in subsection 3.2. SAT score was normed to $N(0,1)$.

Table 14: Logit Marginal Effects on the Probability of Social Sciences or Humanities Final Major Conditional on Social Sciences or Humanities not being the Initial Major

	Specification			
	(1)	(2)	(3)	(4)
No Initial Major	0.395	0.397	0.388	0.391
	(0.039)	(0.039)	(0.040)	(0.041)
Female	0.218	0.201	0.214	0.230
	(0.042)	(0.043)	(0.043)	(0.044)
Black	0.171	0.053	0.014	-0.025
	(0.062)	(0.072)	(0.074)	(0.071)
Hispanic	0.125	0.069	0.102	0.078
	(0.058)	(0.061)	(0.066)	(0.066)
Asian	-0.163	-0.137	-0.097	-0.103
	(0.048)	(0.050)	(0.054)	(0.054)
SAT Score		-0.103	-0.064	-0.030
		(0.029)	(0.031)	(0.032)
Duke Achievement			-0.153	-0.084
			(0.055)	(0.057)
Duke Curriculum			-0.156	-0.131
			(0.052)	(0.053)
Duke Essay			-0.034	-0.043
			(0.048)	(0.050)
Duke Recommendation			0.017	0.054
			(0.048)	(0.048)
Duke Personal Qualities			0.029	0.023
			(0.048)	(0.049)
Year 1 Student Effect				-0.121
				(0.027)
Log likelihood	-454.0	-443.7	-431.7	-416.4
Observations	822			

Note: See Table 1 for a description of the Duke admission's office variables. "Year 1 Student Effect" refers to the first period student effect (α_{i1}) from the grades analysis in subsection 3.2. "No Initial Major" denotes students that reported "do not know" as initial major. SAT score was normed to $N(0, 1)$.

then estimated a logit model of switching majors because of academic background on the sample of those who switched majors. Our controls include those from Table 13 with additional controls for initial major choice. Note that these are switches in the sophomore year and may not be across the broad categories we have been using in the previous parts of this section.

Marginal effects from the logit estimation are presented in Table 15. When we only control for race, gender, and initial major, we observe that blacks and those whose initial major is in the natural sciences, engineering, or economics are more likely to switch because of their academic background. Similar to Tables 13 and 14, adding controls leads to the black coefficient going to zero, shifting the importance of black to academic background measures like the student's SAT, Duke rank, and adjusted first year performance. In contrast, an initial major in the natural sciences, engineering, or economics is associated with higher switching because of one's academic background, regardless of the set of controls used.

5 Conclusion

In this paper we have analyzed how black and white educational outcomes at an elite university vary over time. We have focused on two outcomes: grades and choice of major. An argument in favor of affirmative action in college admissions is that it identifies students with much potential but weak preparation, suggesting recipients should catch up to their more-prepared counterparts over time. While at first blush there appears to be evidence of this as the differences in grades between blacks and whites diminishes over their college careers, we show that this is not due to differential learning. Rather, it results from both changes in how the grade distribution is used over time (the grading distribution is more censored in later years) and changes in course selection.

Changes in course selection result from black and white students having very different persistence rates in the natural sciences, engineering, and economics. While conditional on sex black students have stronger initial preferences than whites for majoring in the natural sciences, engineering, or economics, they are significantly less likely to choose one of these majors for their final major. We show that these differences in persistence rates are fully explained by differences in academic background. Courses in the natural sciences, engineering, and economics are rated more difficult, are associated with higher study times, and have harsher grade distributions than those in the humanities and social sciences. The differences in difficulty levels across course types then works to dissuade individuals with relatively worse academic backgrounds to choose majors in the humanities and social sciences.

Table 15: Change of Major Because of Difficulty

Female	0.062	0.050	0.075	0.071
	(0.053)	(0.054)	(0.054)	(0.053)
Black	0.186	0.088	0.066	0.000
	(0.077)	(0.082)	(0.083)	(0.078)
Hispanic	0.137	0.084	0.099	0.066
	(0.072)	(0.074)	(0.076)	(0.077)
Asian	0.087	0.111	0.134	0.109
	(0.112)	(0.119)	(0.114)	(0.089)
Initial Major Nat Sci/Eng/Econ	0.120	0.142	0.147	0.141
	(0.074)	(0.074)	(0.074)	(0.071)
SAT Score		-0.091	-0.065	-0.009
		(0.030)	(0.032)	(0.033)
Duke Achievement			-0.112	-0.016
			(0.074)	(0.069)
Duke Curriculum			-0.032	-0.008
			(0.064)	(0.062)
Duke Essay			-0.009	-0.005
			(0.060)	(0.060)
Duke Recommendation			-0.038	0.020
			(0.062)	(0.062)
Duke Personal Qualities			0.075	0.076
			(0.062)	(0.061)
Year 1 Student Effect				-0.187
				(0.032)
Log likelihood	-217.7	-212.1	-208.7	-190.8
Observations		377		

Note: Logit marginal effect on the probability of switching major due lack of academic preparation. See Table 1 for a description of the Duke admission's office variables. "Year 1 Student Effect" refers to the first period student effect (α_{i1}) from the grades analysis in subsection 3.2. SAT score was normed to $N(0, 1)$.

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6 Appendix: Drop-out Bias and Non-Response Bias

The Registrar's Office data provided information on students who were not enrolled at the end semester in each survey year. Non-enrollment might occur for multiple reasons including academic or disciplinary probation, medical or personal leave of absence, dismissal or voluntary (including a small number of transfers) or involuntary withdrawal. Fewer than one percent of students ($n = 12$) were not enrolled at the end of the first year; about three percent by the end of the second year ($n = 48$) and just over five percent ($n = 81$) by the end of the senior year. We combined all of these reasons and tested for differences in selected admissions file information of those enrolled versus not enrolled at the end of each survey year. The test variables included racial ethnic group, SAT verbal and mathematics score, high school rank (where available), overall admission rating (a composite of five different measures), parental education, financial aid applicant, public-private non-religious-private religious high school and US citizenship. Of over 40 statistical tests, only two produced significant differences (with p-value less than 0.05): (1). At the end of the first year, dropouts had SAT-verbal scores of 734 versus 680 for non-dropouts; (2). by the end of the fourth year, those who had left college had an overall admissions rating of 46.0 (on a 0-60 scale) while those in college had an average rating of 49.7. No other differences were significant. We conclude that our data contain very little drop-out bias.

We conducted similar tests for respondents versus non-respondents for each wave for the same variable set plus college major (in 4 categories: engineering, natural science/mathematics, social science, humanities), whether or not the student was a legacy admission, and GPA in the semester previous to the survey semester. Seven variables show no significant differences or only a few small sporadic differences (one wave but not others), including racial ethnic category, high school rank, admissions rating, legacy, citizenship, financial aid applicant, and major group. However, several other variables show more systematic differences:

- Non-respondents at every wave have lower SAT scores (math: 9-15 points lower, roughly one-tenth to one-fifth of a standard deviation; verbal: 18-22 points lower, roughly one-third of a standard deviation).

- Non-respondents have slightly better educated parents at waves one and three, but not waves two and four.

- Non-respondents at every wave are less likely to be from a public high school and somewhat more likely to be from a private (non-religious) high school.
- Non-respondents have somewhat lower GPA in the previous semester compared with respondents (by about one-quarter of a letter grade).

These differences are somewhat inconsistent in that they include lower SAT and GPA for non-respondents, but higher parental education and private (more expensive) high schools. In general, the non-response bias is largest in the pre-college wave and smaller in the in-college waves even though the largest response rates are in the pre-college wave. In general, we judge the non-response bias as relatively minor on most variables and perhaps modest on SAT measures.