Appendices for Online Publication

Appendix A. Ranking within Caste and Effective Rank

Our empirical approach requires a constructed variable, *effective rank*, which indicates the priority a student has in admission, as determined by performance on the entry exam and affirmative action policy.

We proceed by first constructing an *entry exam rank* variable based on exam scores and following the tie-breaking procedures outlined in the text (e.g., footnote 11). We rank students 1 through *N*, and let R_i denote the rank for student i. Then we define entry rank, $E_i = 1 - \frac{R_i}{N}$, thereby normalizing *entry exam rank* to lie between 0 and 1. Importantly, gender and caste play *no* role in the construction of this variable.

Now affirmative action rules mandate that a specified share of seats in each college be reserved for members of disadvantaged castes, and the rules mandate furthermore that within each caste (including the Open category) one third of seats be reserved for women. Panel A of Appendix Table A shows seat share assignments under the applicable rules. The law thus mandates that college priority be determined by *exam rank within caste-gender groups*, rather than by overall rank on the entry exam.

To illustrate, consider the following hypothetical case with two groups: 1000 Open caste students (say caste 0) and 300 disadvantaged caste students (caste 1) who generally score less well on entry exams than Open students. In our example, affirmative action policy reserves one third of seats for caste-1 students at each college (one caste-1 seat for every two caste-0 seats). College choice proceeds as follows: students are ranked by exam *within* caste, and then the top-ranked student chooses first, the second-ranked student choose next, and so forth. Of course, the top-ranked caste-1 students have the same choice as the two top-ranked caste-0 students. Then as the choice process proceeds, if caste-1 and caste-0 students hold similar views about the desirability of available college seats, the 10^{th} ranked caste-1 student will have a similar choice set as the 20^{th} ranked caste-0 student, the 100^{th} ranked caste-1 student will have a similar choice set to the 200^{th} ranked caste-0 student, and so forth.

Effective rank is a construct that reflects the process we have just described. Let effective rank for student i in caste j be

(A1) $r_{ij} = 1 - \frac{s_0 R_{ij}}{N_0 s_j}$,

where s_0 is the share of seats reserved for open students, N_0 is the number of open students, R_{ij} is the rank of student i within caste j, and s_j is the share seats reserved for caste j. In our example, with $s_1 = \frac{1}{3}$ and $s_0 = \frac{2}{3}$, effective rank for a caste-1 student is $r_{i1} = 1 - \frac{s_0 R_{i1}}{N_0 s_1} = 1 - \frac{2R_{i1}}{1000}$, while effective rank in the open caste is $r_{i0} = 1 - \frac{R_{i0}}{1000}$. Notice that a 10th ranked caste-1 student ($R_{i1} = 10$) indeed has the same effective rank as a 20th ranked caste-0 student ($R_{i0} = 20$). Also notice that the lowest rank caste-1 student ($R_{i1} = 300$) has an effective rank of 0.40, the same as the caste-0 student with rank $R_{i0} = 600$. The lowest rank caste-0 student has effective rank 0. Figure 1 shows patterns similar to our example.

We construct effective rank as defined in (A1) for the 14 caste/gender groups in our analysis. Notice that effective rank is scaled to be essentially 1 for the top-scoring student in each demographic group, and 0 for the lowest ranked open male student. Effective rank values for men and women of all castes are shown in Figure 1, and are used in all regressions reported in the paper.[30]

For our counterfactual analysis, we compare outcomes (attendance, achievement, graduation) if choice priority were determined without affirmative action to outcomes when choice is determined with affirmative action. Without affirmative action, choice priority is determined by entry rank, E_i, which has mean of 0.5 when averaged across all individuals. Hence, to assure that effects attributed to affirmative action are not an artifact of scaling, we require a normalization of effective rank such that its mean is also 0.5. We define *normalized effective rank* as $r_{ij}^N = 1 - \frac{R_{ij}}{k s_j}$, with k chosen so that the mean of this construct equals 0.5. Variables r_{ij} and r_{ij}^N are linearly related, and thus either of these measures of effective rank yields the same fit and statistical significance in the equations we estimate. For ease of interpretation, we

[30] If *effective rank* (r_{ij}) works as intended, it should be a substantially better predictor of a student's college quality than a student's *entry exam rank* (E_i). In our analysis of the impact of college quality on student performance (Section III.C) we estimate a "first-stage regression" that has college quality as a function of effective rank, caste/gender fixed effects, and a latent ability construct, finding a coefficient on r_{ij} of 0.140 (s.e., 0.049). Remarkably, when we include also E_i, the coefficient is on r_{ij} is still 0.140 (s.e., 0.051) and the coefficient on E_i is -0.002 (s.e., 0.041).

report in the text regression results using r_{ij}. Then to avoid over-stating the effects of affirmative action in our counterfactual analysis, we use normalized effect rank to obtain the results reported in Tables 6 – 8.

A modification was made in 2001 to the seat selection process by *Government Order 550 of the Department of Higher Education*. The following detail regarding the seat selection process is needed to explain this change: In the seat selection process, Open seats for men are filled first. At this stage, seats are provisionally filled based on overall rank on the entry exam. All individuals, regardless of caste and gender provisionally take a seat at this stage based on their entry exam rank until all seats are filled. Then Open-caste women seats are filled next, with all women regardless of caste provisionally taking seats based on entry exam rank among women until all seats are filled. Any woman who qualifies for a more-preferred seat at this stage may take it in lieu of the seat provisionally chosen on the previous round. Next, within each disadvantaged caste, seats for males are filled first. Caste members, regardless of gender, provisionally take seats at this stage based on rank within caste until all seats are filled, and any caste member who can obtain a preferred seat to that taken on the Open round may do so. Next, within each disadvantaged caste, seats for women are filled in order of rank among women within caste, and any woman who can obtain a more preferred seat than provisionally occupied on a previous round may take the more-preferred seat.

Prior to 2001, seats provisionally taken and subsequently vacated reverted to the caste/gender group to which the seats were originally allocated. Virtually all members of disadvantaged castes are able to improve their seat selection by using their caste/gender quota. Hence, prior to 2001, almost all seats provisionally taken by disadvantaged castes in the Open round reverted to members of Open castes. This was changed by *Government Order 550*. The new implementation specified that, rather than reverting to Open caste members, all vacated Open seats first be offered to students of the same caste/gender as the student who vacated the seat. For students from the highly-disadvantaged ST and SC groups, this has little impact on the allocation of seats. Very few of these students are ranked highly enough in the entry exam to obtain attractive seats during the Open round, and, hence, almost all seats provisionally chosen by ST's and SC's on the Open round revert to Open castes. However, many members of the less-disadvantaged BC-B and BC-D castes have sufficiently high entry exam rank to obtain relatively attractive seats on the

Open round. When they subsequently exercise their caste priority to obtain a still better seat, the seats they vacate are taken by lower-ranked members of their castes. The impact, then, is essentially to expand the allocation of seats to BC-B and BC-D students, while reducing the number of seats actually available to Open caste members, particularly Open caste men.

The net impact for the cohort we study is given in Panel B of the Appendix Table A. In calculation of effective rank for our empirical analysis, we use the effective seat shares shown in Panel B.[31] For students in the most disadvantaged groups—ST, SC, BC-A, and BC-C—there was negligible effect on the proportion of allocated seats. However, the implementation of the law effectively increased the allocation of seats to the BC-B and BC-D men and women, while lowering the remaining seats available to Open students.

There is one final twist to the admission process. There were too few applicants among ST and SC students to fill allocated seats. This doesn't change the way we calculate effective rank for these students; indeed, it is precisely why even very low-performing ST and SC students have such a high effective ranks. However, under Government Rule 550 these seats revert to Open students. So, in the end, 0.300 of seats effectively went to Open men and 0.192 to Open women.

Appendix Table A. Effect of Seat Allocation Due to Affirmative Action

	ST	SC	BC-A	BC-B	BC-C	BC-D	Open
A. Allocation of Seats by Initial Quota							
Men	0.040	0.100	0.047	0.067	0.007	0.047	0.333
Women	0.020	0.050	0.023	0.033	0.003	0.023	0.167
All	0.060	0.150	0.070	0.100	0.010	0.070	0.500
B. Effective Allocation of Seats Under Government Order 550							
Men	0.040	0.100	0.051	0.122	0.007	0.097	0.250
Women	0.020	0.050	0.023	0.049	0.003	0.035	0.153
All	0.060	0.150	0.074	0.171	0.010	0.132	0.403

[31] Notice that the sum of the "effective allocations" is somewhat greater than 1. This is because some ST and SC seats are essentially allocated twice—first they are provisionally allocated to ST/SC students, and, when subsequently vacated, they are made available to Open caste students. We adopt a straightforward extension of the normalization described above so that mean effective rank equals mean entry rank.

Appendix B. Modelling College Attendance

An applicant to an engineering college in the State we study potentially has three choices: attend an engineering college in the State, attend some other academic institution, or choose the no-college option. We observe only whether the applicant attends an engineering college in the State. To frame our choice model, let $U_{ij}^{e}(a_{ij}, r_{ij}, c_{ij}^{e})$ denote utility in the engineering college to which student *i* in caste/gender group *j* is admitted. Here, a_{ij} denotes the student's academic aptitude, r_{ij} denotes effective rank of the student in his or her caste/gender group, and c_{ij}^{e} is the cost of attending an engineering college. We then write utility of the engineering college option as the sum of a deterministic component, denoted with lower-case *u*, and an idiosyncratic term ε_{ij}^{e}:

(B1) $$U_{ij}^{e}\left(a_{ij}, r_{ij}, c_{ij}^{e}\right) = u_{ij}^{e}\left(a_{ij}, r_{ij}, c_{ij}^{e}\right) + \varepsilon_{ij}^{e} .$$

For most students in our data, an engineering college will be the best available academic option. However, exceptionally able students can be expected to gain admission to a more prestigious institution, e.g., one of the Indian Institutes of Technology (IIT). Let $\delta_{ij} = 1$ for a candidate who is admitted to such an institution, and who also prefers that institution to the no-college option, and let $\delta_{ij} = 0$ otherwise. Also, let c_{ij}^{a} be the cost of attending this alternative academic institution. Then if ε_{ij}^{a} is the idiosyncratic utility shock of the non-engineering college option, we can write

(B2) $$U_{ij}^{n}\left(a_{ij}, c_{ij}^{a}\right) = \delta_{ij}\left[\, u_{ij}^{a}\left(a_{ij}, c_{ij}^{a}\right) - u_{j}^{0}(a_{ij}) \,\right] + u_{j}^{0}(a_{ij}) + \varepsilon_{ij}^{a} ,$$

where $u_{ij}^{a}\left(a_{ij}, c_{ij}^{a}\right)$ and $u_{j}^{0}(a_{ij})$ denote, respectively, the deterministic component of utility in an alternative academic institution and in the no-college option. Note that effective rank is not included in these two utility expressions because effective rank affects priority only for admission to an engineering college in the State we study. Also note that we have a subscript *j* on each utility option, permitting the possibility of systematic differences across castes and gender in the valuations of benefits of college attendance or non-attendance.

Of course the probability of admission to an alternative competitive institution, such as an IIT, is itself a function of ability and also plausibly of caste and gender. Letting $\rho_j(a_{ij}) = E(\delta_{ij})$ be the probability, conditional on aptitude, that applicant *i* in group *j* obtains admission to a more elite institution, we have

(B3) $$U_{ij}^n(a_{ij}, c_{ij}^a) = \rho_j(a_{ij})[\, u_{ij}^a(a_{ij}, c_{ij}^a) - u_j^0(a_{ij})\,] + u_j^0(a_{ij}) + \varepsilon_{ij}^n\,,$$

where

(B4) $$\varepsilon_{ij}^n = \varepsilon_{ij}^a + [\delta_{ij} - \rho_j(a_{ij})]\,[\, u_{ij}^a(a_{ij}, c_{ij}^a) - u_j^0(a_{ij})\,].$$

Thus ε_{ij}^n impounds both an idiosyncratic preference shock from (B2), as well as factors that influence whether a member of group *j* with aptitude a_{ij} is admitted to a superior alternative academic institution.

Now an applicant who gains admission to an engineering college in our State will matriculate if (B1) is greater than (B3), that is, when

(B5) $$[\, u_{ij}^e(a_{ij}, c_{ij}^e, r_{ij}) - u_j^0(a_{ij})\,] - \rho_j(a_{ij})\,[\, u_{ij}^a(a_{ij}, c_{ij}^a) - u_j^0(a_{ij})\,] > \varepsilon_{ij}^n - \varepsilon_{ij}^e\,.$$

The first term in the left-hand side is the difference in the deterministic components of utility between and engineering college and the no-college option. The second term is the probability of admission to an academic institution preferred to an engineering college multiplied by difference in the deterministic components of utility between the alternative academic institution and the no-college option. Below, we assume that the idiosyncratic shocks are i.i.d. normal, implying a probit specification for the binary choice of attending or not attending an engineering college.

For most students who take the entry examination for engineering colleges, an engineering college will be their best academic option. The probability of admission to an IIT or comparable institution will be an increasing and convex function that is near zero throughout much of its domain and increases sharply for aptitudes in the right tail of the distribution. Thus, for most applicants, the second term of the left-hand side of equation (B5) will be approximately zero, implying that the deterministic portion of the choice between an engineering college and the no-college option is

(B6) $$[\, u_{ij}^e(a_{ij}, c_{ij}^e, r_{ij}) - u_j^0(a_{ij})\,]\,.$$

Clearly (B6) must be increasing in r_{ij} because those of higher rank within their caste/gender group have higher priority in engineering college choice. If the academic gain from attending an engineering college is greater for more able students, then this latter expression is also increasing in a_{ij}; for most ability levels, we expect the probability of matriculation in our engineering colleges to be increasing in a_{ij}. At a relatively high levels of aptitude, though, the middle term in (B5) comes to dominate. For very-high aptitude students, an increase in a_{ij} improves the probability of admissions to an IIT or other high-prestige institution and thus *reduces* the probability of matriculation to one of our engineering colleges.

To summarize, our model has two clear predictions: First, the probability of matriculation at an engineering college is increasing in r_{ij}, and second, it is an inverted U-shaped function in aptitude a_{ij}. This motivates an empirical specification in which we estimate the attendance probability using a polynomial in effective rank and a polynomial in aptitude—allowing flexibility in the effects of these constructs on matriculation. We could proceed with a probit model of college attendance, and indeed did so in an earlier version of the paper. In the current version, we use a linear probability model, which yields qualitatively similar results.

Appendix C. Regression Results for Attendance

Estimates of our attendance equation (1) are not easily interpretable because of the presence of higher-order terms. Thus in the main paper we show key results using graphs (Figures 2 and 3). Below are coefficient estimates:

	(1) Men		(2) Women	
Independent Variables	Coefficient	(s.e.)	Coefficient	(s.e.)
Constant	0.121**	(0.029)	-0.552	(0.501)
ST	-0.123**	(0.036)	-0.316**	(0.068)
SC	0.027	(0.026)	-0.126**	(0.045)
BC-A	0.063**	(0.016)	-0.078**	(0.028)
BC-B	0.050**	(0.013)	0.028*	(0.013)
BC-C	0.041	(0.024)	0.032	(0.031)
BC-D	0.050**	(0.013)	0.032*	(0.015)
(Effective rank)	0.646**	(0.199)	9.087*	(4.630)
$(\text{Effective rank})^2$	-6.040**	(1.170)	-41.916*	(17.02)
$(\text{Effective rank})^3$	19.877**	(3.095)	88.409**	(30.15)
$(\text{Effective rank})^4$	-21.067**	(3.528)	-82.074**	(25.62)
$(\text{Effective rank})^5$	7.279**	(1.459)	28.078**	(8.418)
High School Score	-0.017**	(0.004)	0.009	(0.007)
Entry Exam Score	0.073**	(0.022)	0.095*	(0.037)
High School Score × Entry Exam Score	0.074**	(0.005)	0.079**	(0.010)
High School Score Squared	-0.065**	(0.003)	-0.077**	(0.006)
Entry Exam Score Squared	-0.034**	(0.005)	-0.059**	(0.010)
High School Score Squared × Entry Exam Score	0.011**	(0.004)	-0.012	(0.010)
High School Score × Entry Exam Score Squared	-0.017**	(0.004)	-0.006	(0.011)
High School Score Cubed	-0.007**	(0.001)	-0.009**	(0.003)
Entry Exam Score Cubed	-0.003	(0.001)	0.002	(0.003)

Notes: n = 80,771 for men and n = 35,421 for women. This is a linear probability regression (dependent variable is 1 for matriculation). R^2 = 0.31 for regression (1); R^2 = 0.35 for regression (2).

Appendix D. Calculating Standard Errors in Table 8

In this Appendix we provide details for our calculation of standard errors on the estimated mean impacts of affirmative action reported in Table 8.

As noted in Appendix A, all analysis can be done either with our *effective rank* variable or a *normalized effective rank* variable that this linearly related to the former; fit and statistical significance is the same either way. Our counterfactuals ask what would happen if admission policy was based on *entry exam rank,* E_i (with no preference by caste/gender) and it is appropriate to use the *normalized effective rank,* r_i^N*,* for this exercise because it has been normed so that the two constructs have the same mean.[32]

Let β_m and b_m be, respectively, the population coefficient and estimated coefficient on normalized effective rank in the first-year achievement regression. For student i define y_{i1} to be achievement with affirmative action and define y_{i2} be the corresponding achievement in the absence of affirmative action. Let ε_{i1} be the error term in the achievement equation with affirmative action and let ε_{i2} be the error term that would have appeared in the achievement equation if there were no affirmative action. Then the difference in achievement for student i*,* with and without affirmative action, is

(D1) $$y_{i1} - y_{i2} = \beta_m\left(r_i^N - E_i\right) + \varepsilon_{i1} - \varepsilon_{i2} .$$

The corresponding difference in *predicted* outcomes is

(D2) $$\hat{y}_{i1} - \hat{y}_{i2} = b_m\left(r_i^N - E_i\right).$$

The error in the estimated impact of affirmative action is thus

(D3) $$e_i = (\hat{y}_{i1} - \hat{y}_{i2}) - (y_{i1} - y_{i2}) = (\beta_m - b_m)\left(r_i^N - E_i\right) + \varepsilon_{i1} - \varepsilon_{i2}.$$

Under our assumptions, $E(e_i) = 0$.

With his in mind, consider a caste/gender group j of size n_j individuals. The error in the mean estimated effect of affirmative action group j is

(D4) $$\bar{e}_j = (\beta_m - b_m)\left(\bar{r}_j^N - \bar{E}_j\right) + \sum_i(\varepsilon_{i1} - \varepsilon_{i2})/n_j.$$

[32] Effective rank has a *j* subscript, indicating caste/gender, which we suppress here to make notation cleaner.

If we let s_m be the standard error on b_m, the variance of the object in (D4) is

(D5) $$Var(\bar{e}_j) = s_m^2(\bar{r}_j^N - \bar{E}_j)^2 + \frac{\sum_i Var(\varepsilon_{i1} - \varepsilon_{i2})}{n_j^2},$$

which can be written,

(D6) $$Var(\bar{e}_j) = s_m^2(\bar{r}_j^N - \bar{E}_j)^2 + \frac{(\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2)}{n_j}.$$

Consider the numerator in last term of (D6). The variance under the counterfactual (σ_2^2) is unknown, but it is natural to assume that it will be approximately the same as under the existing college choice regime, which suggests taking $\sigma_2^2 = \sigma_1^2$. The correlation of the error terms ρ is also unknown. The natural interpretation of the error in the achievement equation is that it is a combination of several factors. One factor is the student-specific fit for higher education in engineering that is revealed when the student attends a college. Other factors might be termed idiosyncratic luck (the student had the good fortune to connect with a motivating teacher, the student was ill during the exam week, etc.). The student-specific component would tend to impart a positive value to ρ, while the luck component would favor a zero value of ρ. There is no natural interpretation that would yield a negative value of ρ. The most conservative reasonable approach (yielding the largest variance estimate) thus sets $\rho = 0$, in which case (D6) becomes

(D7) $$Var(\bar{e}_j) = s_m^2(\bar{r}_j^N - \bar{E}_j)^2 + \frac{(\sigma_1^2 + \sigma_2^2)}{n_j}.$$

To give an example, in the estimated achievement equation the standard error of the regression is 0.61, so $\hat{\sigma}_1^2 = 0.61^2$. The standard error of the estimated coefficient on normalized effective rank is $s_m = 0.124$. Consider the smallest male caste group, ST. For this group $n_j = 720$ and $(\bar{r}_j^N - \bar{E}_j) = 0.424$. Substituting into (D7), and taking the square root, we have the estimated standard error (0.062) reported in the first row of Panel A in Table 8. If we had taken the less-conservative route of ignoring the second term in (D7), our estimated standard error would have been 0.053.