Women in Engineering:
A comparative study of barriers across Nations
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Table of Contents

EXECUTIVE SUMMARY .................................................................................................................. 3
INTRODUCTION .............................................................................................................................. 4

Chapter 1: College Level Barriers for Female Engineers - A Comparison of Trends in India and United States ........................................................................................................................................ 6
ABSTRACT ........................................................................................................................................ 6
1.1 BACKGROUND: The Leaky Pipeline .............................................................................................. 6
1.2 LITERATURE REVIEW .................................................................................................................. 7
1.3 METHODOLOGY .......................................................................................................................... 8
1.4 QUANTIFYING THE BARRIERS ................................................................................................. 9
1.5 COLLEGE BARRIERS: .................................................................................................................. 13
   1.5.1 College Barrier 1: Isolation ...................................................................................................... 13
   1.5.2 College Barrier 2: Intellectual Intimidation ............................................................................ 14
   1.5.3 College Barrier 3: Lack of confidence .................................................................................. 15
   1.5.4 College Barrier 4: Perceived Barriers Overall and Perceived Challenges ......................... 17
1.6 PRE-COLLEGE BARRIERS ......................................................................................................... 18
1.7 CONCLUSION .............................................................................................................................. 19
REFERENCES .................................................................................................................................... 21

Chapter 2: GENDER RATIOS in TOP ENGINEERING INSTITUTIONS: What we can learn from comparisons between U.S. and India ................................................................................................ 22
ABSTRACT ........................................................................................................................................ 22
2.1 INTRODUCTION .......................................................................................................................... 22
2.2 BACKGROUND: A Disparity in Applicant to Admit Ratios ......................................................... 23
2.3 SELF-SELECTION FOR FEMALE ENGINEERS IN INDIA ...................................................... 27
2.4 THE SELECTION PROCESS: INDIA versus the UNITED STATES ........................................ 28
2.5 CONCLUSION AND RECOMMENDATIONS ............................................................................. 32
REFERENCES .................................................................................................................................... 34
APPENDIX ....................................................................................................................................... 35
CONCLUSION ................................................................................................................................... 38
EXECUTIVE SUMMARY

*In-college environmental barriers for female engineers in India do not exist as they do in the United States.*

Studies in the United States show evidence of a “chilly climate” in engineering colleges, whereby female engineers experience isolation, psychological intimidation and loss of confidence that leads to high female dropout rates during college. In testing for these same environmental barriers in B-tech programs in India, we find little evidence of any in-college environmental barriers linked to gender, and no evidence that college is a place of leakage for females in the engineering education and career path. On the other hand, there is indicative evidence that females report lower self-perception of ability and preparedness than males in India.

*Females consistently report to be more confident, feel more respected and motivated than males in both engineering and non-engineering degrees.*

Females in both engineering and non-engineering disciplines consistently report to be more confident, open to working with males and respected as compared to male students. In fact the female engineering students come out to be the most confident among all the groups. This not only shows lack of hostile environment for women in higher education in India, but also points to a confident new generation of women in India. It is worth investigating whether women in India show the same confidence in other contexts such as in workplace and household environments.

*Selection criteria for India’s top engineering colleges, namely high discrete cut-off on tests scores, leave capable females engineers systematically disadvantaged in the admissions process.*

We observe that the representation of females in top engineering institutions in India is much lower than that in the US top engineering schools. The most likely explanation for the high male-female ratios in India’s top engineering colleges is the use of high discrete cut-off on tests scores in the selection criteria (apart from weak self-selection effects). If the test itself and selection through high cut off test scores is not changed in any way, then the American lesson is that top-tiered engineering programs will remain stagnant with MFR’s of 7:1, or thereabouts, at best. Given that there is little evidence that the standardized admission tests, both in India and the US, have strong correlation to engineering success, a high cutoff on these test scores is unwarranted. A comparison of the selection process with U.S. top engineering colleges shows that a more holistic selection process may even the playing field for capable female candidates. Policymakers should focus on expanding the parameters used as selection criteria to identify India’s most capable female talent and not just depend on scores of a written test. As soon as the test and selection process are fixed, and ratios can begin to improve, then we should begin to see improvements in other factors such as self-selection and improvement in the general confidence of young aspiring females, their parents and society. While this may be an optimistic view, it is likely that changing the test not only will have the capacity to improve MFR’s immediately but also to start a virtuous cycle of positive feedback loops in other factors influencing the participation of India’s most capable females in engineering.
INTRODUCTION

The fight for “women's rights” is one that has crossed time and space – penetrating countries and cultures, developing and developed alike. Amartya Sen argued that “inequality between women and men is not everywhere the same”\(^\text{1}\) – that is to say, that gender disparity is multi-faceted and complex, taking on different unique histories and outcomes within different contexts. The question of gender disparity in developing countries is particularly pervasive, as this is not only where disparities are often the greatest, but also where the empowerment of women can lead to the greatest benefits. Calling for global priority of the education of women, world leaders and development policymakers often tout women as the greatest untapped resource of the developing world. Studies show that every additional year that a mother attends school yields 20% higher wages, 10% fewer child deaths, and translates to her child staying in school an additional half year.\(^\text{2}\) Hence, the education and empowerment of women is one that not only can immediately benefit growing economies, but also offers sustainable long-term change by affecting future generations.

A recent Thompson Reuters study ranked India 19\(^\text{th}\), last place out of the G20 countries, on gender equity.\(^\text{3}\) Despite targeting India as a place where much work needs to be done, the study also recognized the strides that the country has taken. Women have held top political positions in India since the ‘60’s, the number of girls in primary school has risen substantially, and the economic growth of the last two decades has empowered women in the workforce. South Asia’s deputy director for U.N. Women, Sushma Kapoor, defines “two Indias: one where we see more equality and prosperity for women, but another where the vast majority of women are living with no choice, voice or rights.”\(^\text{4}\) Kapoor identifies a kind of abstract separation of two spheres in India – one where women have progressed as empowered individuals, and one in which women remain trapped with little prospects for equity. If improvements in gender equity are to be made for women in India, one must ask in what way the two Indias interact, if at all. What are the mechanisms that have enabled women to step forward as empowered individuals in Indian society, and what are those mechanisms that hold women back?

Though women have remained traditionally under-represented in the technology and engineering sector in India, recent increases in the number of aspiring female engineers present an opportunity for this question to be investigated. These trends raise the question of which of the two Indias the engineering space represents. Answers to this question are not only important for the sake of “women’s rights” but are also central to questions concerning the landscape of the Indian economy. Recent studies surrounding equality of opportunity in India have investigated engineering as a lens of social mobility that can offer us insights into the increasing inequality accompanying newly emerging prospects following India’s newly liberalized economy (Krishna 2011). Engineering has shown itself as a space where social mobility is possible in the face of rising inequality, and it is important to understand how engineering might offer equal opportunity for males and females alike. While women are seen as the untapped resources of the developing world, engineers are seen as the innovators who provide the building blocks of society. If utilized properly, both can open doorways for increased growth and development.

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Research on women in engineering in India remains scarce. While this domain remains largely unexamined in the Indian context, the underrepresentation of women in the sciences and engineering has been examined in greater depth in many other countries. Specifically, several studies in the United States have investigated the barriers present for the advancement of women in the sciences and engineering. Literature in the U.S. identifies the presence of the “leaky pipeline,” whereby women systematically drop out of the science and engineering track at various points along the education and career ladder. Is this same dynamic present for women in engineering in India, and if so, how so and to what extent?

This study analyzes trends for women in engineering in India to better understand which of Kapoor’s spheres engineering represents. In what ways does engineering represent a space of progress for women in India and in what ways do women still remain disadvantaged? We ask where the most prominent barriers and leaks may be occurring for women in engineering in India. The growing participation of women in India’s engineering colleges offers us the opportunity to examine the “leaky pipeline” at the college level, where very little prior investigation has been done. Hence, we begin our inquiry by focusing on trends in the admission and attendance of females in B-tech programs throughout India.

This study does two investigations:

- A look at environmental factors at the college level: are the same barriers and points of leakage present for women in India as in the United States? If not, where are the relevant points of leakage for aspiring female engineers in India?

- A study into factors influencing the gender ratios at the top engineering schools in India and the US to investigate why the gender ratios are pegged so differently in the top institutions in the two countries.
Chapter 1: College Level Barriers for Female Engineers - A Comparison of Trends in India and United States

ABSTRACT
Literature on the representation of women in science, technology, math and engineering (STEM) careers in the United States has uncovered the presence of a "leaky pipeline," (Seymour 2002) whereby women systematically drop out of the STEM track at various points along the education and career ladder. A comparison of trends for female engineers in India and the United States at the college level reveals differences in where women are leaking from the pipeline in each country. In this article, we primarily study barriers faced by women within the college in pursuing engineering and also look at some aspects of pre-college barriers. Whereas a "chilly climate" presents itself in college environments in the United States, we find an absence of such in-college environmental barriers in B-tech (engineering) programs in India. However, there is some evidence that pre-college barriers such as lack of preparation and female self-perception of their ability may inhibit aspiring female engineers from pursuing and gaining admission to B-tech programs. Whereas college is not a significant point for leaks in the pipeline in India, leaks may occur for females before reaching the college level.

1.1 BACKGROUND: The Leaky Pipeline
Since the 1970's, U.S. policymakers and higher education institutions have focused on the under-representation of women in science, technology, math and engineering (STEM) education programs and careers. Despite great strides in gender equity in the United States over the past century, research has identified the presence of the "leaky pipeline" (Seymour 2002) in STEM programs, whereby women systematically drop out of the STEM track at various points along the education and career ladder. This trend disproportionately increases as women move up the chain, and is particularly pervasive in engineering. While women earn 58% of all undergraduate degrees in the country, they only earn 19% of engineering undergraduate degrees. Moreover, in 2010, 30% of enrolled students in engineering programs were female, but only 18.5% received degrees. Hence, a "leaking" of females out of the engineering path is prominent at the college level in the United States. Growing concern that the loss of capable talent at the college level would translate into limited workforce potential in these careers spurred multiple investigations of the causes and consequences of the "leaky pipeline" (Seymour 2002).

While significant leaks at the college level are occurring for female engineers in the United States, the recent growth in women's participation in engineering colleges in India presents an interesting contrast. Recent findings from the Aspiring Minds 2011 Employability Report show that the male-female ratio (MFR) in engineering colleges in India is 1.96, whereas MFR's in engineering colleges in the United States are as high as 4.61. The MFR in other bachelor degrees (art, science and commerce) in India is 1.09. One observes that the gender ratio in engineering colleges lag behind aggregate trends in higher education in India, but the gap is not that big as observed in the US.

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While a growing body of literature surrounding the “leaky pipeline” exists in the United States, little research to date has investigated trends for female engineers in India at the college level. However, the leaky pipeline analogy presents an analytical framework by which we can investigate these trends for women in engineering in India. Are similar trends occurring for female engineers in India and are leaks occurring at similar places in the pipeline? Where are they different, where are they the same, and why?

An understanding of differences in these barriers can provide learning across cultures and may offer insight into larger trends occurring for women in engineering. The larger questions we wish to investigate are the general causes of gender exclusion, which may differ by regions, cultures and socio-economic conditions. It is presumptuous to believe that the reasons in the US data reveal the full extent of cause of the phenomena. The Indian data provides another interesting opportunity since the gender ratio is much better which may provide a fresh perspective to look at the issue.

Our primary focus in this study is to identify the barriers females face once they have succeeded in gaining admission to a B-tech program, with a minor investigation into what challenges these women faced before. We investigate whether the females in India experience a chilly climate in colleges, as compared to the USA and also if they face any different kind of barriers not documented in the US based studies.

1.2 LITERATURE REVIEW

Several empirical studies have been conducted at the pre-college and college level in the United States to discern what barriers might block women from pursuing and succeeding in STEM programs. At the pre-college level, studies find that disparities in teacher treatment of boys and girls leads to a lowering of girls confidence in math and science, and builds negative stereotypes around females pursuing the sciences (AAUW 1992, 2010).

In the United States, the college level for women in engineering constitutes a pervasive point of “leaks” in the pipeline. About as many girls as boys leave high school in the U.S. prepared to pursue STEM careers, but only 20% of STEM degrees are earned by females (AAUW 2010). Studies in the United States evidence a heightened vulnerability of females, above and beyond that of males, to drop out of undergraduate engineering and science programs, with persistence rates systematically lower among female engineers.9 In the early 1990s, a collection of researchers in the U.S. focused their attention on trends in the pipeline at the undergraduate level.

A debate surfaced surrounding what mechanisms were driving these leaks. While some studies suggest that the lower mathematic and spatial ability of women is a possible factor in female underrepresentation in engineering (Baenninger and Newcombe 1995), several studies have refuted this claim at the college level, finding no correlation between performance levels and the decision to drop out of science and engineering programs. Instead, a “chilly climate” hypothesis identifies discriminatory behavior affecting females in engineering that may come from both teachers and male classmates (see Strenta 1993, Seymour 1995, Brainard 1998). Consequently, consistent findings among several studies document feelings of isolation, lack of confidence and aversion to competition as driving factors in female dropout rates in science and engineering programs (Seymour 1995). To this day, the presence of the “chilly climate” pervades engineering

9Strenta et all 1993: persistence rate of men in engineering programs to be between 61% and 39%, while female persistence rates are between 46% and 30%.
programs, and has spurred recent investigations into the most effective interventions to improve barriers for females in engineering (Fox 2009).

Our study aims to test whether the same environmental barriers that are present in U.S. STEM programs also exist for female engineers in India. Inevitably, since India presents an entirely different context than the United States, we anticipate that other barriers may exist in India, or may present themselves in different ways. For example, socio-cultural differences may cause discriminatory treatment to come more from parents than teachers at the school level in India, or concerns about safety or the female role within the family may inhibit female college choices. Apart from investigating the present barriers existing in the US, we also investigate existence of other kinds of barriers in India.

1.3 METHODOLOGY

1.3.1 Instrument design and data gathering

Two instruments were designed to gather data on both an engineering and non-engineering population at the college level: a written survey and case interviews conducted both in person and by telephone.

The written survey was designed to identify trends in both in college and pre-college barriers\textsuperscript{10}. The instruments were based on a body of literature identifying common barriers and trends for women in engineering in the United States and a set of those hypothesized for India. These questions included the perception of environment in the college, academic preparation, interactions with the other gender and competitiveness among others. Some questions also asked about self-perception of prior achievements and preparation and the perceived barriers faced leading up to college. The case interviews comprised follow-up questions based on observations from the data and also to get a first-person account.

The sample itself consists of both males and females and engineers and non-engineers college students who took the AMCAT (Aspiring Minds Computer Adaptive Test) between 10 November 2012 and 15 December 2012. All test takers are students in their pre-final or final year of college. A total of 2200 engineering and 2800 non-engineering candidates filled the survey and 62 candidates were interviewed.\textsuperscript{11} The sample captures a representative sample of engineers across different states and tier of colleges.

Administering the survey at AMCAT events provides an arena for representative sample collection across genders and career choices at the college level. It must be noted that in all these AMCAT events, all students in the final or the pre-final year took the AMCAT and there are no self-selection effects. The resulting sample enables comparison of females pursuing a B-tech degree with males pursuing B-tech degrees and with females pursuing non-engineering degrees. Administering the survey at AMCAT events provides a proctored test environment with serious mentality.

Though we only surveyed final year students, based on reports from college authorities and students, we have found no evidence of engineering female dropouts in India. This was confirmed from both the college administration and a sample of students. In none of the colleges, any significant percentage of women had dropped out (<5%, which was similar for male students).

\textsuperscript{10} Part of the pre-college barrier data was used for a different investigation.
\textsuperscript{11} Only engineering students were interviewed. We shall be interviewing non-engineering students in future.
Hence, we should be able to see evidence of the pre-college and college barriers that the women gaining admission into B-tech programs in India have experienced.

One-on-one in-depth case interviews with male and female engineers and non-engineers were conducted in the north and/or metro areas, with some telephonic interviews conducted with female engineers from the south. Additionally, females with an all-rural educational background were specifically sought out to gain further insight into unique barriers that such females might have faced.

Throughout the interviews, probing was used to re-ask questions and clarify answers, thus ensuring we received answers that satisfied the intent of each question.

1.3.2 Limitations of the Data
While the data collected enables comparison between responses from female engineers, male engineers and female non-engineers, it only offers insight into variation across those students who have decided to attend college. Data does not provide insight into those women who chose not to pursue careers, or those women who may have aspired to have a career (in engineering or otherwise) but faced barriers that kept them from making it to the tertiary level of education. Such barriers may include socio-economic disadvantage, resistance of parents or community, or lack of academic preparation.

The data is sufficient to highlight barriers that either persist up to college years or whose cause initiates during college life. For instance, lack of attention in school may discourage females to take up sciences and leak even before joining college. We find it unreasonable to believe that only those females who faced no barriers personally and observed no barriers around them made it to engineering schools. Hence, our data could uncover pre-college barriers through reports from women who have experienced such barriers, but nevertheless aspired to apply, successfully gained entrance to and persisted in engineering programs. To uncover this, we asked female respondents in case interviews, "Do you think girls got less attention in schools..." in third person and "Do you think you received more, less or equal attention from teachers in school?" in second person. This is in line to what is observed in several college surveys in the U.S., where large proportions of female engineers report pre-college barriers. Under the assumption that the same proportion of females is able to break barriers in both countries, similar trends should be visible in the Indian engineering college-level population.

1.4 QUANTIFYING THE BARRIERS
In this section, we quantify whether a barrier exists or not by comparing the endorsement rates of males and females on respective questions in the survey and case interviews. Table 1 shows the main barriers reported for female engineers in the United States at both the pre-college and college level, and the ways in which we see these barriers manifest for female engineers and non-engineers in India. We identified studies in the United States literature that reported barriers that both are associated with the "chilly climate" and that are similar to those that our data uncovers in India.

We classify the existence of the barriers according to the following criteria:

- **Gender Difference**: when the data shows a positive difference between the proportion of female and male engineers reporting a particular barrier, we classify a

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12 Inferences from case interviews are indicative since the sample size is small.
difference of less than 5% as weak, less than 10% as moderate and rest as high
difference. For negative difference, we report no differential barrier for females.

- **Effect Size:** We look at the proportion of females affected by a barrier. We classify
  below 10% of the group reporting the barrier as Low, above 10% as moderate and
  over 20% of the group as high.
<table>
<thead>
<tr>
<th>BARRIERS</th>
<th>FINDING IN U.S. (Study)</th>
<th>Effect Size in U.S./ Data Type</th>
<th>ENGINEERS Data (Source)</th>
<th>Diff. btw. males &amp; females, Effect</th>
<th>P- Value</th>
<th>Effect Size</th>
<th>NON-ENGINEERS Data (Source)</th>
<th>Diff. btw. males &amp; females, Effect</th>
<th>P- Value</th>
<th>Effect Size</th>
</tr>
</thead>
</table>
| **Self-Perception of Ability** | Girls assess selves lower than boys with same mathematical ability  
(Correll 2001)** | High | Being male is associated with higher “mathematical self-assessment” than females of similar ability  
(coefficient 0.245, p-value <0.05) | 63.33% of males and 51.72% of females in the top 10%  
(according to AMCAT scores) rate themselves in top 10% in quantitative ability.  
(Survey Data)+ | 11.61% None | 48.28% High | 33.85% of males and 30.48% of females in the top 10%  
(according to AMCAT scores) rate themselves in top 10% in quantitative ability.  
(Survey Data) | 3.37% Moderate | 0.28 | 69.52% High |
| **Prior Academic Preparation** | Inadequate high school preparation in subject area and study skills  
(Seymour 1995)*** | None | Similar proportions of males and females cite this concern  
(15% of females who left engg. mid program and 40% of all female engineer students report this concern,  
15% of males who left engg. and 38% of all male engg. students overall cite this concern. | 10.26% of females and 3.2% of males report lack of academic preparation  
as a barrier to their education or career pathway (Case Interviews) | 7.06% Moderate | 10.26% Moderate | No case interviews | - | - |
| **Isolation** | Reports of female isolation increased substantially during the 4-year program  
(Brainard 1998)**** | High | Reported feelings of isolation among female engineers increased from 7.6% during freshman year to 51.8% during senior year | 7.84% of females and 19.28% of males report feeling left out in an academic setting  
(Survey Data) | -11.44% None | 7.84% Low | 17.83% of females and 28.03% of males  
report feeling left out in an academic setting  
(Survey Data) | -10.20% None | 0.00 | 17.83% Moderate |
| **Intellectual Intimidation: Behavior of Males in Group Environments**  
(perpetuated by stereotypes) | Male engineers reported not knowing how to relate to or work with women in academic situations requiring collaborative effort  
(Seymour 1995) | Qualitative | Male engineers reported not knowing how to relate to or work with women in academic situations requiring collaborative effort  
(Seymour 1995) | 11.59% of males and 3.49% of females reported a preference  
for same gender study groups (Survey data) | -8.11% None | 3.49% Low | 19.21% of males and 16.78% of females reported a preference  
for same gender study groups (Survey data) | -2.44% None | 0.11 | 16.78% Moderate |
Table 1. Barriers at the Pre-College and College Level: U.S. and India

<table>
<thead>
<tr>
<th>BARRIERS</th>
<th>FINDING IN U.S. (Study)</th>
<th>Effect Size in U.S./ Data Type</th>
<th>ENGINEERS Data (Source)</th>
<th>Diff. btw. males &amp; females, Effect</th>
<th>P-Value</th>
<th>Effect Size</th>
<th>NON-ENGINEERS Data (Source)</th>
<th>Diff. btw. males &amp; females, Effect</th>
<th>P-Value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellectual Intimidation: Behavior of Males in Group Environments (perpetuated by stereotypes)</td>
<td>Women report male comments of inappropriate jokes, make them feel unwelcome, devalue them (Seymour 1995)</td>
<td>Qualitative</td>
<td>96.15% of females feel respected by their peers (men and women alike), 91.53% males feel respected. (Survey data)</td>
<td>-4.62% None</td>
<td>0.00</td>
<td>3.85% Low</td>
<td>92.92% of females feel respected by their peers (men and women alike), 90.27% males feel respect. (Survey data)</td>
<td>-2.65% None</td>
<td>0.02</td>
<td>7.08% Weak</td>
</tr>
<tr>
<td>Overall Confidence</td>
<td>Lack of self-confidence increases throughout college years. These trends are associated with other environmental factors related to institutional setting. (Brainard 1998 and AAUW 2010)</td>
<td>High</td>
<td>Reports of lack of self confidence increased monotonically from 23% to 44.5% from freshman to senior year for female engineers</td>
<td>-3.7% None</td>
<td>0.00</td>
<td>1.29% Low</td>
<td>94.22% of females and 92.11% of males report confidence in ability to succeed. (Survey Data)</td>
<td>-2.11% None</td>
<td>0.05</td>
<td>5.78% Weak</td>
</tr>
<tr>
<td>Confidence in Math and Science Abilities</td>
<td>Loss of self-confidence in these subjects was found to be correlated with drop-outs and uncorrelated with performance (Brainard 1998)</td>
<td>High (p-value&lt;0.05)</td>
<td>No evidence of lack of confidence or increased dropout rates among females.</td>
<td></td>
<td></td>
<td></td>
<td>No evidence of lack of confidence or increased dropout rates among females.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Barriers Overall</td>
<td>Increase in reports of barriers for female engineers over 4 year program (Brainard 1998)</td>
<td>High</td>
<td>Perceived barriers increase for undergraduate female engineers from 77.2% reporting barriers in freshman year to 97.1% reporting barriers by senior year.</td>
<td>3.5% Weak</td>
<td>0.05</td>
<td>48.7% High</td>
<td>No case interviews</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Whereas more males rate themselves highly among top 10% candidates, the difference goes away as soon as we look at top 25% candidates. Here 64.70% of females and 62.92% of males rate themselves among top 25% (or above). Thus the effect seems to be exist only towards the very top. Please refer to Appendix.

**pre-college barriers refer to those barriers faced by our sample of female engineers before gaining admission to a B-tech program. These are not representative of those pre-college barriers faced by all females before college, but rather are specific to females who select into the engineering stream.

**sample size 17,424

*** sample size 460

**** sample size of 672
Overall, females in engineering report much less environmental barriers at the college level than in the U.S. With respect to the gender differences in engineering in India, for all barriers examined, apart from self-perception of academic preparation/ability/barriers, effects are non-existent. Within barriers with weak gender differences, only one case comes from survey data, while the other two are from case interviews and are thus indicative. The effect size of the barrier for females in engineering is mostly low and in most cases more males are affected by a barrier than females.

In particular, females with high quantitative ability (top 10% in AMCAT quantitative ability) rate themselves lower on mathematical ability (Row 1 of Table 1) as compared to similar males. Secondly, more females report lesser academic preparation as a barrier to their career path or education. Nevertheless, they report no discrimination from teachers or peers in college or any lack of confidence.

Females in non-engineering degrees consistently report more barriers than those in engineering. They seem to be less confident, more shy and less competitive. This clearly shows that the barriers for females are not a function of the engineering degree. The comparative trends between males and females remain qualitatively similar for both engineering and non-engineering graduates. Males consistently report more barriers than females.

We shall now investigate each of the barriers reported in the table in detail.

1.5 COLLEGE BARRIERS:
The most notable outcome of the survey and case interviews is that female engineers in India report much less psychological barriers at the college level than are reported in the U.S. These reports indicate a significant difference in the way female engineers feel about the college environment in India from that of female engineers in the United States, and suggest that the “chilly climate” does not exist for females in India as it does for females in the U.S. College-level barriers that show large effects in the U.S. with non-existent to weak effects in India are psychological alienation, intellectual intimidation, and lack of confidence, and perceived barriers overall.

We now look at each of these barriers in detail and compare their presence in India and the US.

1.5.1 College Barrier 1: Isolation
In 1991, the University of Washington launched a longitudinal study to evaluate the efficacy of the Women in Engineering Initiative, designed to promote the support and retention of women in the undergraduate engineering program. Brainard (1998) summarized the findings of a longitudinal study that interviewed and surveyed a total of 672 female engineers over 6 cohorts. By surveying the same students every year from freshman to senior year, the Brainard study identified self-reported and perceived barriers for female engineers in the program. While the Brainard study did not survey male engineers as a comparison group, it still identified some clear trends over time for female undergraduate engineers at this university, and is one example of “the chilly climate.” Specifically, Brainard found that reports of isolation and psychological alienation from female engineers actually increased over the course of the 4-year program, from 7.6% in the freshman year to 51.8% in senior year.

To address the question of isolation, we asked respondents if they ever felt left out in an academic setting. Only 7.84% of the female engineers answering this question reported such feelings, while

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13 The difference goes away when we look at top 25% females and males. Please refer to Appendix.
19.28% of male engineers reported feeling left out. The difference is significant (p-value 0.00). Out of those students who choose to pursue an engineering degree, males are perhaps more likely to feel such sentiments of isolation or alienation than females in India. Thus, females don’t face this barrier any more than males.

In non-engineering population, 17.83% females and 28.03% males reported feeling left out. This clearly shows that less percentage of females find themselves left out in engineering and thus this barrier doesn’t increase as a function of the engineering degree.

1.5.2 College Barrier 2: Intellectual Intimidation
Numerous studies in the U.S. cite trends of females in engineering programs reporting feelings of isolation or psychological alienation due to a male dominant environment where male students were often hostile toward female students (GAO 2004). Seymour (1995) found that reports of intellectual intimidation for female engineers in the United States are linked to working in groups setting or social environment. In individual interviews, women reported experiencing negative attitudes and behaviors of male peers in science and engineering programs. Female engineers expressed anger about male remarks and jokes that they assume were aimed to devalue them and make them feel unwelcome. Women also reported male assumptions that females were incompetent in practical matters. Women reported men not allowing them to participate in lab experiments or other practical projects and would often order them around (Seymour 1995).

To identify if females at engineering colleges in India felt these environmental challenges at the college level, we asked a series of question, about working in groups and achieving success in the college environment.

**Male attitudes within group settings**
Seymour (1995) cited a difficulty for men in engineering programs to work with or relate to women within group environments. Underlying this preference was a belief that “smartness” in mathematics was believed to be a male attribute (Seymour 1995). Whereas we found some hesitancy in males to work in female groups (11.59% males preferred same gender groups), we found much lesser hesitancy in females (3.49%). When we investigated this question further in case interviews, we found that the males who cited preference for working in male only groups were not comfortable working with females because they lacked exposure to this opportunity in the past. Hence, these reported feelings appear to be more rooted in lack of exposure to working environments with females than in stereotypes that females are inferior.

Again when we look at non-engineering population, 19.21% of males and 16.78% of females reported a preference for same gender study groups. This in turn shows that lesser percentage of females in engineering prefer same gender study groups and thus this barrier isn’t a function of the engineering degree either.

We further asked candidates the level to which they agree with the statement “*When working in groups, I find that my peers respect my intelligence.*” The pattern of response for males and females is shown in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Moderately Agree</th>
<th>Neutral</th>
<th>Moderately Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Males</strong></td>
<td>45.64%</td>
<td>45.89%</td>
<td>7.98%</td>
<td>0.25%</td>
<td>0.25%</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td>51.34%</td>
<td>44.81%</td>
<td>3.56%</td>
<td>0.30%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

**Table 2. Perceptions of Peer Respect from Engineers by Gender**

Women in Engineering: A comparative study of barriers across Nations
The question itself was geared toward understanding if females felt any sense of intimidation when working with others in a group environment. Responses indicate that a positive work environment is present within engineering colleges for both males and females, slightly favoring females though. 45.64% of males and 51.34% of females strongly agree that their intelligence is respected, and 45.89% males and 44.81% females moderately agree. Notably, 0.30% females and 0.25% males moderately disagreed and 0.25% males and no females strongly disagreed. Even though the difference between males and females is significant (p-value 0.00), the value of difference is small.

Table 3 below for non-engineers, where similar to engineers, females find themselves more respected. On the other hand, engineering females find themselves more respected than females in non-engineering degree.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Moderately Agree</th>
<th>Neutral</th>
<th>Moderately Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>46.94%</td>
<td>43.33%</td>
<td>6.13%</td>
<td>1.64%</td>
<td>1.97%</td>
</tr>
<tr>
<td>Females</td>
<td>49.16%</td>
<td>43.76%</td>
<td>5.40%</td>
<td>0.74%</td>
<td>0.93%</td>
</tr>
</tbody>
</table>

Table 3. Perceptions of Peer Respect from Non-Engineers by Gender

1.5.3 College Barrier 3: Lack of confidence

Lack of confidence has been found to be a barrier for females pursuing science and math both at the pre-college and college level in the U.S.(Correll 2001, Brainard 1998, AAUW 2010), and has been cited as a prevalent factor contributing to the drop out problem for females in engineering programs. Lack of confidence has been found not only to increase as female engineers progress through undergraduate programs, but also to be correlated with dropout rates (Brainard 1998, Strenta 1993). Most notably, Brainard(1998) found an upward trend in lack of confidence as females moved through undergraduate engineering programs. Over the course of the 4-year program, reports nearly double from students’ sophomore to senior year, increasing from 23% to 44.5% from freshman to senior year.

To test if these same trends were occurring for female engineers in India, respondents were asked to rate the following on a 5-point Likert scale: “Please specify the degree to which you agree with the following statement: “I am confident in my abilities to succeed in my place of study.” While the Brainard study captures decreases in confidence levels over time, our study is able to ascertain if there is any evidence of lack of confidence that is specifically linked to gender (through male female differences within the engineering group) Table 4 captures the responses of the engineering group by gender.

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>Group Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly agree</td>
<td>70.75%</td>
<td>80.37%</td>
<td>75.07%</td>
</tr>
<tr>
<td>Moderately agree</td>
<td>24.25%</td>
<td>18.40%</td>
<td>21.63%</td>
</tr>
<tr>
<td>Neither</td>
<td>1.75%</td>
<td>0.31%</td>
<td>1.10%</td>
</tr>
<tr>
<td>Moderately disagree</td>
<td>2.75%</td>
<td>0.31%</td>
<td>1.65%</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>0.50%</td>
<td>0.61%</td>
<td>0.55%</td>
</tr>
</tbody>
</table>

Table 4. Levels of Confidence by Gender in Engineering
Table 5. Levels of Confidence by Gender in Non-Engineering

One interesting observation is that running a chi-squared statistic shows significant difference between levels of confidence in academic ability reported by women of engineering as compared to men (p-value = 0.00). Females report slightly higher levels of confidence than the men of engineering. When we compare the response of non-engineers on the same question (Table 5), we find the engineering women more confident than the non-engineering ones.

Whereas the above questions investigate female confidence to succeed in an academic setting in engineering colleges, we also looked at female confidence (self-assurance) in extra-curricular settings. Respondents were asked if they were to organize an event or festival in their college, if they would find this activity discouraging. Only 2.06% females and 5.53% males responded affirmatively that they would be discouraged. The difference was significant (p-value=0.00). This question aimed to discern if there was any significant difference between the challenge males and females feel when trying to operate within the college environment, without indicating the intent of the question, which may potentially bias their answer. Not only do very small proportions of females express a lack of self-assurance, but this proportion is also smaller relative to the males.

Seymour (1995) also noted that women were averse to competitive environment which led to dropouts. We asked the question, “I find competitive environments motivating”. The results are provided in Table 6. We find that a much larger set of females, i.e. 75.73% versus 59.22% males strongly agreed to the statement, whereas 0.29% females and 0.49% males strongly disagreed. The difference was significant (p-value=0.00). We also asked if the respondent found the environment competitive, to which 87% females and 81% males answered in affirmative. In Table 7, we report how non-engineering students responded to the question. Consistent with other findings, females in engineering found competition most motivating among all engineering and non-engineering students.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Neither</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>59.22%</td>
<td>33.50%</td>
<td>4.61%</td>
<td>2.18%</td>
<td>0.49%</td>
</tr>
<tr>
<td>Females</td>
<td>75.73%</td>
<td>21.05%</td>
<td>2.05%</td>
<td>0.88%</td>
<td>0.29%</td>
</tr>
</tbody>
</table>

Table 6. Levels to which males and females in engineering find competitive environment motivating

<table>
<thead>
<tr>
<th>Gender</th>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Neither</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>57.01%</td>
<td>32.50%</td>
<td>6.33%</td>
<td>1.97%</td>
<td>2.18%</td>
</tr>
<tr>
<td>Females</td>
<td>65.22%</td>
<td>27.02%</td>
<td>5.23%</td>
<td>1.56%</td>
<td>0.96%</td>
</tr>
</tbody>
</table>

Table 7. Levels to which males and females in non-engineering find competitive environment motivating
Based on this data, we see no evidence that females in engineering colleges are systematically less confident than males in the same program. Nor do we see any evidence that a “chilly climate” at the college level is eroding female confidence in engineering programs in the same way we see in the United States.

1.5.4 College Barrier 4: Perceived Barriers Overall and Perceived Challenges

One important aspect of the “chilly climate” is the overall sense that one faces barriers in their education and career path. Brainard (1998) found that the sense of perceived barriers increased for females in engineering over the 4 year program at the University of Washington, with the finding that by their senior year 97.1% of female engineers were reporting barriers of some kind. Contrastingly, in our case interviews, only 48.7% of females in their pre-final or final year in engineering programs in India report barriers of any kind, with the notable comparison that 45.2% of males report barriers of some kind. This difference is just indicative and not significant, given the small sample size. Even if there may be some underlying reason for women in India systematically underreporting such barriers, there is no significant difference in the proportion of men reporting barriers in their education and career path, thus suggesting that the barriers that are reported are not necessarily linked to gender.

In the survey, we also asked respondents about perceived challenges before attending college. Respondents were asked to rate each of the following challenges they anticipated when choosing their current career path on a scale of 1 to 4.

<table>
<thead>
<tr>
<th>REASON</th>
<th>Mean Female</th>
<th>Mean Male</th>
<th>(p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of background knowledge in my field of study</td>
<td>2.18</td>
<td>2.18</td>
<td>0.96</td>
</tr>
<tr>
<td>Disapproval from friends and family</td>
<td>1.75</td>
<td>1.79</td>
<td>0.04***</td>
</tr>
<tr>
<td>Barriers to advancement in the workplace</td>
<td>2.01</td>
<td>2.12</td>
<td>0.09**</td>
</tr>
<tr>
<td>Barriers to pay rise at work</td>
<td>2.09</td>
<td>2.25</td>
<td>0.01***</td>
</tr>
<tr>
<td>Lack of financial resources</td>
<td>2.00</td>
<td>2.18</td>
<td>0.00***</td>
</tr>
<tr>
<td>Difficulty in succeeding</td>
<td>2.00</td>
<td>2.04</td>
<td>0.47</td>
</tr>
<tr>
<td>Lack of confidence</td>
<td>1.86</td>
<td>1.97</td>
<td>0.08**</td>
</tr>
<tr>
<td>Lack of support from members of the field</td>
<td>1.92</td>
<td>2.03</td>
<td>0.04**</td>
</tr>
<tr>
<td>Lack of necessary basic skills</td>
<td>1.93</td>
<td>2.06</td>
<td>0.03***</td>
</tr>
</tbody>
</table>

Table 8. Challenges Anticipated by Engineers by Gender

Notably, there are statistically significant differences between male and female rankings of most anticipated challenges (disapproval from friends and family, barriers to advancement in the workplace, barriers to pay rise, lack of financial resources, lack of confidence and lack of basic necessary skills). Despite these differences, the mean rating for males was consistently higher than that of females. While self-reported perceptions have their limitations as evidence, this could indicate that males in engineering may actually perceive more challenge than female engineers. Nevertheless, these differences could also indicate that men in engineering are more empowered to complain about the challenges they feel than women, and will report a sense of these challenges in greater proportion.
To investigate how these trends are linked to engineering within the female population, we compare the response of female engineers and non-engineers and examine the differences among those females pursing higher education who are in engineering versus those who are not.

<table>
<thead>
<tr>
<th>REASON</th>
<th>Mean Engineers</th>
<th>Mean Non-Engineers</th>
<th>(p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of background knowledge in my field of study</td>
<td>2.18</td>
<td>2.33</td>
<td>0.09**</td>
</tr>
<tr>
<td>Disapproval from friends and family</td>
<td>1.69</td>
<td>1.84</td>
<td>0.09**</td>
</tr>
<tr>
<td>Barriers to advancement in the workplace</td>
<td>2.01</td>
<td>2.17</td>
<td>0.07**</td>
</tr>
<tr>
<td>Barriers to pay rise at work</td>
<td>2.09</td>
<td>2.25</td>
<td>0.07**</td>
</tr>
<tr>
<td>Lack of financial resources</td>
<td>2.00</td>
<td>2.28</td>
<td>0.00***</td>
</tr>
<tr>
<td>Difficulty in succeeding</td>
<td>2.00</td>
<td>2.13</td>
<td>0.08**</td>
</tr>
<tr>
<td>Lack of confidence</td>
<td>1.86</td>
<td>2.14</td>
<td>0.00***</td>
</tr>
<tr>
<td>Lack of support from members of the field</td>
<td>1.91</td>
<td>2.17</td>
<td>0.01***</td>
</tr>
<tr>
<td>Lack of necessary basic skills</td>
<td>1.93</td>
<td>2.18</td>
<td>0.00***</td>
</tr>
</tbody>
</table>

Table 9. Challenges Anticipated by Females by Degree

Table 9 indicates that not only are female non-engineers reporting greater challenges on average than engineering females, but their means are also greater than male engineers. This at least refutes the hypothesis that women may systematically report perceived challenges in lower proportions to males due to a hesitation to speak about challenges. Moreover, these data also indicate that there are greater and more significant differences between female engineers and non-engineers than there is between female engineers and male engineers.

Hence, overall, we see an absence of the “chilly climate” for females in engineering colleges in India. Environmental barriers that lead to psychological alienation, intellectual intimidation, and lack of confidence are not present in India in the same way they are in the United States. Now we will turn our investigation to a minor look into the challenges faced by the women in India’s B-tech programs before college.

1.6 PRE-COLLEGE BARRIERS

While our data does not show substantial evidence for the same pre-college barriers found in the United States, female engineers do report some evidence of barriers faced before gaining admission into B-tech programs. Since the trends are not large enough to be significant, we include data on these reports in the appendix (see Appendix A) and give a short summary here. Survey data shows some trend that female engineers are less likely than males with similar ability to perceive themselves as being in the top 10% of their class. Further, in case interviews, females report lack of academic preparation and competition in entrance exams as barriers to their educational achievement and career path. These reports suggest that some of the pre-college barriers identified in the U.S. literature are likely present in larger proportions at the school level. Thus, while we focus our report here in this section on college barriers, these additional reports on pre-college barriers indicate that leakage may be a threat for females pursuing engineering before they even reach college.
1.7 CONCLUSION

The most notable outcome of this analysis is the absence of the “chilly climate” at the college level in India. Evidence from this study indicates that engineering women in India do not perceive barriers to their education at the college level in the same way female engineers in the U.S. do. Furthermore, women engineers in India are not dropping out mid-degree in undergraduate programs as they do in the United States. Hence, the college level itself does not seem to be a point of “leakage” for females in India. Secondly, we find that the barriers that exist for females in engineering in India are present in a larger proportion for females in non-engineering degrees. This clearly shows that the barriers faced by women in India do not increase as a function of being in engineering discipline.

While there is indication that some barriers still exist at the pre-college level, those women who do gain admission and persist in engineering colleges in India are confident and happy in their environment and do not appear to be experiencing alienation or isolation of any kind. In fact, women in engineering report lesser barriers than men in engineering, men and women in non-engineering degrees. It is also noteworthy that women report lesser barriers than men in both engineering and non-engineering degrees. These findings show that the developing world, more specifically India, is doing better in some dimensions of gender equity than the West. It will be useful to further investigate whether the phenomena of the confident female is observed in other contexts such as those in workplace or the household in India.

We conclude with confidence that in-college environmental barriers for female engineers in India do not exist as they do in the United States. However, further investigation into pre-college barriers is warranted based upon preliminary findings in this study.

While the absence of the “chilly climate” offers a possible explanation for why more females stay in college (hence no college level leakage), our data does not indicate why more females decide to take up engineering in India in the first place. One hypothesis could be that while the “chilly climate” in STEM programs may discourage more females from pursuing these pathways, a lack of “chilly climate” in India may create a virtuous cycle whereby pre-college females hear positive experiences from female engineers, which creates more incentive for females to pursue this stream. Additionally, another hypothesis could be that different perceptions of engineering in India and the United States, both as a career path in and of itself, and also as a career path for women, may be influencing women to make different choices based on different social influences.

A broader view of this hypothesis may be that females in the United States are leaking both at the pre-college and college level due to both internal and external forces. The “chilly climate” in engineering colleges, which is overall absent in India, acts as an external force that deters aspiring female engineers from persisting in the United States. Perceptions of engineering as a career path also constitute internal forces that may be influencing female engineers in India more positively. Evidence from the case interviews responses show that engineering is seen as a highly respected role in society with great economic prospects and job opportunities in India. Greater economic incentive and less environmental discrimination at the college level may explain why larger proportions of females in India are pursuing and persisting in engineering. These findings pave the way for future research at the pre-college level. Studies that focus on socio-cultural perceptions of engineering and stereotypes of female’s ability to pursue a science based career may lend more insight into what forces may be positively or negatively influencing trends in female decisions to take up engineering as a career path in India. Additionally, further research on pre-college barriers for aspiring female engineers can offer insight into what forces maybe driving leaks in the pipeline.
before reaching the college level. This research will be important to uncovering the ways in which the development of capable female talent for the growing engineering and technology sector in India can be better accessed.
REFERENCES


Chapter 2: GENDER RATIOS in TOP ENGINEERING INSTITUTIONS: What we can learn from comparisons between U.S. and India

ABSTRACT
A comparison of gender ratios in the U.S. and India show the United States achieving significantly better gender equity at the top engineering institutions. Whereas male-female ratios (MFR's) in these institutions in the U.S. range from 4:1 to 1.4:1, India’s premier engineering colleges maintain high MFR’s ranging from 14:1 to 8:1. We investigate the degree to which self-selection and the selection process are likely to play a role in such high MFR’s in India. We find that while there are moderate self-selection effects within the highest performing females in India, these trends are not enough to explain the high MFR’s seen in top tiered engineering colleges. Instead, it is likely that the selection criteria used for these institutions, namely high discrete cut-off tests scores, leave capable aspiring females engineers systematically disadvantaged in the admissions process. We recommend that India’s premier engineering colleges use a more holistic admissions process that uses additional parameters besides test scores to identify the highest quality female talent.

2.1 INTRODUCTION
Results from our college tier analysis indicate that gender exclusion may be occurring in higher proportions at the top institutions in India. While the United States evidences more leaks in the pipeline at the college level, and has lower representation of females in undergraduate engineering programs overall, a comparison of gender ratios at the top institutions in the U.S. and India show the United States achieving significantly better gender equity at the top.

Figure 1 shows the relationship between MFRs and the ranking of the top 100 B-tech programs in India.

Figure 1. Ranking of top 100 colleges v. MFR’s

Figure 1 shows a steep increase in gender ratios within the top 10 institutions in India. For IIT’s, the very top institutions in India, MFR’s range from 14:1 to 10:1, and even in the next batch of top tier institutions, NIT’s and top state run colleges (such as NSIT and DTU), one sees MFR’s of 8:1. In contrast, the top engineering institutions in the United States maintain gender ratios as low as 1.4 (MIT)\(^{14}\) and 3.76\(^{15}\) (Stanford and Berkeley). This spurs the deeper question of what is happening at

\(^{14}\)This statistic is derived from 2011 data. Total female undergraduate engineers at MIT in 2011: 843, Total males: 1176. Total students 2019. Male-female ratio is 1.4 to 1.
the top for engineering institutions in India, and how does this compare to trends in the United States? If the United States is indeed doing better in the top institutions, then what policies might the U.S. have used that could also improve gender ratios in India? Are these differences due to recruitment or admissions policies, or some other actions taken in the U.S.?

We begin our investigation by comparing admissions trends at these top institutions in India and the U.S., and asking whether this disparity in the gender ratios is due to the admission process itself (selection) or self-selection issues. If these disparities are indeed due to the admissions process, then what are the differences in selection process in India and in the US for these top institutions? If these different selection processes lead to different outcomes (in gender balance or otherwise), then how can we judge which process is better? What should the true end goal of an admission process be and how effective are current admission processes in achieving such goals?

To answer these questions, we turn to publically available data, which can provide us with applicant to admit ratios and admissions selection criteria and outcomes.

2.2 BACKGROUND: A Disparity in Applicant to Admit Ratios

To compare trends in admissions for top tiered institutions, we compare applicant to admit ratios in MIT in the U.S. and the IIT's in India. Since undergraduate engineering programs are often small programs within a large university, admissions data only indicates selection pressure for the larger university but not engineering alone. We choose MIT as a comparable university to the IIT's because while it offers several STEM programs besides engineering alone, it is a highly competitive technical institute that has similar trends in gender ratios to U.S.'s other top tiered engineering institutions. Though the comparison is not perfect, it can still offer insight into trends in the U.S. relative to India.

Table 10 shows the most recent available applicant to admit ratios for MIT and IIT. For IIT, we use the numbers appearing for and clearing the IIT-Joint Entrance Exam (JEE). Since the clearing of the JEE is the primary admissions criteria for IIT's, we compare male and female clearing rates to admittance rates in MIT to compare selection rates at both institutions.

<table>
<thead>
<tr>
<th></th>
<th>MIT 2011-12</th>
<th>IIT 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Male Applicants</td>
<td>12,443</td>
<td></td>
</tr>
<tr>
<td>Total Female Applicants</td>
<td>5,466</td>
<td></td>
</tr>
<tr>
<td>MFR in applicant pool</td>
<td>2.27</td>
<td></td>
</tr>
<tr>
<td>Total Male Admits</td>
<td>891</td>
<td></td>
</tr>
<tr>
<td>Total Female Admits</td>
<td>851</td>
<td></td>
</tr>
<tr>
<td>Admittance Rate Males</td>
<td>7.16%</td>
<td></td>
</tr>
<tr>
<td>Admittance Rate Females</td>
<td>15.57%</td>
<td></td>
</tr>
<tr>
<td>Clearing Rate Males</td>
<td>6.40%</td>
<td></td>
</tr>
<tr>
<td>Clearing Rate Females</td>
<td>1.90%</td>
<td></td>
</tr>
</tbody>
</table>

Table 10. Applicant to Admit Ratios MIT$^{16}$ v. IIT$^{17}$

15 Statistics found in Chen and Nam, UC Berkeley
Although both MFR’s in the applicant pools (2.27 for MIT and 2.2 for IIT) and selection rates for males (7.16% for MIT and 6.4% for IITs) are comparable in both institutions, admissions ratios for females are widely different. Even if we know nothing about the comparable quality of the two female pools, we do know that females are applying to MIT and IITs in similar proportions relative to males, but are being selected at drastically different rates (15.57% for MIT and 1.90% for IITs).

To better understand how these trends have progressed over time, let us look at more data year by year in both India and the U.S.

2.2.1 Trends in IIT and MIT Admissions
Both the U.S. and Indian governments have taken steps to improve prospects for females pursuing engineering. U.S. interventions range from recruiting and mentoring programs at the high school level to scholarships awarded to young females showing potential in math and science. The primary driving impetus for these efforts is Title IX, legislation banning sexual discrimination in higher education institutions. Most recently, a body of literature in the 1990’s and early 2000’s has spurred action in the U.S. top tiered engineering institutions, which led to a range of interventions to improve female participation and persistence in STEM higher education programs. Similarly, the Indian government and IIT’s have taken some steps to improve prospects for females pursuing education at top institutions by way of reduced fees and grace points on entrance exams. Below we show these trends over time and give some background on the high-level steps taken within each country to try to improve these trends.

2.2.2 A Closer Look at Interventions and Trends in IITs
Since 2005, the Indian government and IIT’s have taken steps to increase the number of girls showing up to take the competitive JEE for entrance into IIT’s. In 2006, IIT’s slashed their application fees in half (Rs 300 for girls while boys still paid Rs 600 (approximately $5.50 and $11 USD respectively). Recently, IIT’s also began offering free test taking for girls, and 30 grace marks to help clear the exam. In 2012, IIT’s allowed free online admissions and a reduced Rs 200 (approximately $4 USD) fee for offline admissions for female applicants.

To gain insight into how these interventions may have affected prospects for females, Table 11 shows clearing rates for females from 2005-2011.

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18 http://www.iitfoundation.org/?p=81
19 http://indiatoday.intoday.in/story/iim-iit-jee-girl-student-application-fee/1/153405.html
20 http://jee.iitd.ac.in/faq2013.php
<table>
<thead>
<tr>
<th>YEAR</th>
<th>Count of Females Taking JEE</th>
<th>Count of Females Clearing JEE</th>
<th>Clearing Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>29291</td>
<td>321</td>
<td>1.80%</td>
</tr>
<tr>
<td>2006</td>
<td>58997</td>
<td><strong>missing</strong></td>
<td><strong>missing</strong></td>
</tr>
<tr>
<td>2007</td>
<td>54025</td>
<td>587</td>
<td>1.09%</td>
</tr>
<tr>
<td>2008</td>
<td>78159</td>
<td>840</td>
<td>1.07%</td>
</tr>
<tr>
<td>2009</td>
<td>98028</td>
<td>1048</td>
<td>1.07%</td>
</tr>
<tr>
<td>2010</td>
<td>113000</td>
<td>1476</td>
<td>1.31%</td>
</tr>
<tr>
<td>2011</td>
<td>108653</td>
<td>1443</td>
<td>1.33%</td>
</tr>
<tr>
<td>2012</td>
<td>150000</td>
<td>2866</td>
<td>1.90%</td>
</tr>
</tbody>
</table>

Table 11. Count and Clearing Rate for Females Taking the JEE 2005-12

The main observation to note from Table 2 is that while the number of females showing up to take the IIT entrance exam has vastly grown (from 29,291 in 2005 to approximately 150,000 in 2012), the female clearing rate itself remains low, vacillating between 1.07% and 1.90%. So even though more females are clearing the exam today in total numbers than in 2005, the likelihood of any individual female succeeding in clearing the exam has not improved. Even with the 30 grace marks awarded to female applicants in 2012, the proportion of females clearing the JEE is nowhere near the 6% clearing rate that boys are able to achieve.

### 2.2.3 A Closer Look at Interventions and Trends in the U.S.
Several interventions and policies have played a role in improving prospects for female engineers in the U.S. Most notably, Title IX has played a role in the increased participation of women in science and engineering education programs by catalyzing efforts leading to shifts in admissions criteria, the elimination of exclusionary quotas and even a push for the development of a less biased SAT.

Triumphs of Title IX

Now we turn to trends in applicant-admit ratios in MIT over the same time span as Table 2. Table 3 shows the number of female applicants, the number of females accepted and female admissions rates from 2004-12.
Table 12. Female Admission Rates for MIT 2004-12

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Female Applicants</th>
<th>Number of Females Accepted</th>
<th>Female Admissions Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004-5</td>
<td>2797</td>
<td>767</td>
<td>26.48%</td>
</tr>
<tr>
<td>2005-6</td>
<td>2832</td>
<td>736</td>
<td>25.99%</td>
</tr>
<tr>
<td>2006-7</td>
<td>3217</td>
<td>719</td>
<td>22.35%</td>
</tr>
<tr>
<td>2007-8</td>
<td>3526</td>
<td>740</td>
<td>20.99%</td>
</tr>
<tr>
<td>2008-9</td>
<td>3932</td>
<td>761</td>
<td>19.35%</td>
</tr>
<tr>
<td>2009-10</td>
<td>4693</td>
<td>812</td>
<td>17.30%</td>
</tr>
<tr>
<td>2010-11</td>
<td>5017</td>
<td>798</td>
<td>15.91%</td>
</tr>
<tr>
<td>2011-12</td>
<td>5466</td>
<td>851</td>
<td>15.57%</td>
</tr>
</tbody>
</table>

Table 12 indicates that there has been an increase in the number of applicants (similar to trends in IIT’s), but the number of females accepted remains relatively constant (ranging from about 750-850), which has led to a steady decrease in applicant-admit ratios over the past decade. Nevertheless, admissions rates for females started high (over 25%) and, even as they have decreased over time, remain high (over 15%). Hence, even before 2005, MIT was aiming for more equal proportions of female representation. Although we cannot know for certain why this is, one hypothesis is that the changing attitudes regarding gender discrimination in the wake of Title IX have contributed to the high female admissions rates we see at MIT.

The steps taken in India and the U.S. were aimed at improving both self-selection effects and selection ratios for females pursuing engineering. However, even with both countries showing efforts to improve female participation in engineering, we observe different trends in admission ratios. While MIT is able to maintain a relatively constant total number of female admits (keeping MFR’s around the current 1.4:1), the main barrier for female participation in top tiered engineering institutions in India appears to be the clearing rate for entrance exams.

These observations point to further areas of inquiry for education policymakers in India striving to improve gender ratios at IITs and other premier institutions. If the current steps taken in India are unable to influence the gender disparity in clearing rates, then what is the problem? Why are MIT and other U.S. top institutions able to achieve better MFR’s than India’s IIT’s? Are self-selection effects pre-college for females in India so skewed that much fewer high quality female candidates are aspiring to gain admission into the top-tiered institutions, or is there something inherent in the selection process that puts females at a disadvantage?

To better understand these trends, we look more closely at both self-selection trends for females pre-college, and at the selection process for admission itself. First, let’s take a look at trends in self-selection for female engineers in India.

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30 statistics from MIT Common Data set found at http://web.mit.edu/ir/cds/
2.3 SELF-SELECTION FOR FEMALE ENGINEERS IN INDIA

One measure of aspiration in India, which can also be seen as a form of self-selection, is the choice of stream taken after 10th Standard. Indian students choose between majorly the Arts, Commerce, and Science (medical and non-medical) streams to follow for 11th and 12th Standard. Whereas it is compulsory to have done science related subjects to pursue science, medicine, or engineering in college, commerce and art colleges also admit students who have pursued a science stream in school, but sometimes with a penalty. Taking non-medical science in senior secondary school is the first expression of students to pursue engineering or science related career. We will use it as a proxy for the same.

We administered a survey across India of candidates who are both engineers and non-engineers (graduates including all major branches such as B.Com., B.Sc., B.A., etc.) to identify whether the highest achieving students in 10th Standard were selecting into a particular stream and if this choice was a function of the student’s gender. As an indicator of a high quality student, we looked at 10th percentage, a measure of ability and performance at the time students decided between streams. To understand the selection process for engineering, we looked at who is choosing the non-medical Science stream (which leads to engineering) versus who is choosing Arts and Commerce streams. Our sample excludes students who chose the medical-science stream since we do not have a representative sample of medical students in our study; however, the important distinction for this analysis is the choice between engineering and graduate streams.

Our sample of approximately 14,000 in size consists of engineers and graduates from across India who would have completed their class 10th in 2006. The sample was carefully chosen such that it represents all major regions in the country and the different degrees in the right proportion. Response rates were similar in all regions and across degrees, and the responding sample also had similar AMCAT scores as the target pool. Thus, the sample is representative in terms of quality, degree choice and regional background. The survey only asked for two pieces of objective information: the stream choice of the candidate in class 11th and the percentage in class 10th. In our analysis, we ask the following question: is the self-selection process different for the highest quality female (as defined by the top 1% and 10%) in terms of their choice of stream (engineering versus graduate streams) relative to male candidates of similar ability? If so, for the purposes of this analysis, we want to understand whether the gender distribution at the top is consequently skewed such that there might be less capable females pursuing non-medical Science who may later aspire to gain entrance into India’s top engineering institutions. If there are less high quality females in the engineering stream relative to males, this may explain the clearing rates we currently see for the JEE.

Table 13 shows the gender distribution at the top 1% and top 10% of each stream in our sample. Percentiles are based on 10th percentages, and are calculated based upon the actual data and no distributional assumption.

<table>
<thead>
<tr>
<th></th>
<th>ARTS</th>
<th></th>
<th>COMMERCE</th>
<th></th>
<th>SCIENCE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top 1</td>
<td>Top 10</td>
<td>Top 1</td>
<td>Top 10</td>
<td>Top 1</td>
<td>Top 10</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>Count/ %</td>
<td>Percent</td>
<td>Count/ %</td>
<td>Percent</td>
<td>Count/ %</td>
</tr>
<tr>
<td>Male</td>
<td>0%</td>
<td>44%</td>
<td>8%</td>
<td>26%</td>
<td>33%</td>
<td>41%</td>
</tr>
<tr>
<td>Female</td>
<td>100%</td>
<td>56%</td>
<td>92%</td>
<td>74%</td>
<td>67%</td>
<td>59%</td>
</tr>
</tbody>
</table>

*percentage indicates gender distribution within top 1 and top 10 percent of sample for each stream
Table 12 shows that the percentage of women in the top 1% or 10% of the distribution is higher in Arts and Commerce as compared to non-medical Science. On the one hand, this indicates that there is an affinity of high-performing females to choose disciplines other than non-medical science, which leads to engineering. One explanation for this moderate self-selection could be that poor admit rates at top engineering institutions might deter high quality aspiring females from pursuing engineering because they see greater barriers to success at the top. However, even after the self-selection, 2/3 of the top 1% sample in non-medical Science is women! This is clearly not in sync with the gender ratios in the top engineering colleges, which show 1 woman for 8-14 men. Clearly, even though there is self-selection, enough high ability women take up non-medical Science, a proxy for engineering aspiration. These trends alone are not enough to explain the gender ratios we see in India’s top-notch engineering colleges. Therefore, self-selection is not the dominant reason and additional barriers must also exist in the selection process for female engineers aspiring to gain entrance at India’s top-notch engineering institutions.

2.4 THE SELECTION PROCESS: INDIA versus the UNITED STATES

To understand how gender imbalances in admissions may be driven by the admission process itself, we investigate the differences in selection criteria in the India and U.S. Looking specifically at IIT’s and MIT as a continuing comparison point, we identify a fundamental difference in the use a cut-off test scores as admission criterion.

2.4.1 Selection Criteria for India’s Top Ranking Engineering Institutions – Clearing the JEE

In order for students to gain admission into IIT’s, candidates must clear the JEE exam. The JEE remains one of the most coveted and highly competitive exams in India, with the overall clearing rate at a low 5% for all applicants. In preparation for the rigor and competition involved in clearing the exam, a huge coaching industry has evolved to prepare students to take the test. Coaching institutes themselves have become a large part of education for aspiring engineers, where coaching institutes take out full page new advertisements to woo top candidates, students take out a year of preparation for the exam following 12th Standard, and coaching preparation can start as early as Grade 8 for some serious students. As a partial explanation for the gender gap on JEE clearing rates, some have argued that underrepresentation of females at India’s best coaching institutes may leave the pool of female applicants systematically underprepared for the JEE. Nevertheless, the highly competitive cut off mark for clearing the JEE narrows the pool of eligible candidates and becomes essentially the sole criteria for admissions into IIT.

2.4.2 Selection Criteria for Admission to U.S. Top Engineering Institutions – A Holistic Process

While the individual engineering schools within the U.S. employ slightly different criteria from each other, these programs overall use a more holistic process than India and consider many other characteristics besides test scores. Admission criteria include a wide range of achievements, including SAT scores, a strong high school record, good letters of recommendation, well-crafted essays, and extracurricular activities. It is possible that this more holistic set of selection criteria creates a more even playing field for females, who may systematically score lower on competitive tests.

31 While female preparedness for the JEE is not our core focus here, some argue that this may be a likely contributor to female clearing rates. For more information and some anecdotal evidence on this hypothesis, see Appendix C.

32 http://collegeapps.about.com/od/sat/a/top-engineering-sat-scores.htm
We now look specifically at MIT’s selection criteria for admissions to gain some insight into how a more holistic process may contribute to the gender ratios we observe. These criteria include academic GPA, admissions essays, recommendations, extracurricular activities, interview, and character/personality qualities. Admissions counselors at MIT look beyond test scores, and even cite the dual role of diversity and merit in the selection process, noting that the two are not mutually exclusive. Scores, grades, teacher recommendations and coursework all go into assessing the merit of a student, and their preparedness for the academic rigor of MIT. Beyond that, MIT uses the concept of diversity to build the best class out of a wide pool of capable applicants. Admissions counselor Chris Patterson says “we are not looking for the thousand students who aced the SAT... we are looking for the best mix of all these students who will together constitute a terrific class.” Hence, test scores are used as one of many criteria to identify who is capable of succeeding, and many other criteria are considered to build the best possible class. This way of using test scores can be seen in the applicant to admit ratios for SAT test scores. Below are the admit ratios for the fall of 2011 applicant pool based on Quantitative SAT scores:

<table>
<thead>
<tr>
<th>SAT Scores</th>
<th>Applicants</th>
<th>Admits</th>
<th>Admit Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>750-800</td>
<td>7805</td>
<td>1071</td>
<td>14%</td>
</tr>
<tr>
<td>700-740</td>
<td>3123</td>
<td>290</td>
<td>9%</td>
</tr>
<tr>
<td>650-690</td>
<td>1700</td>
<td>68</td>
<td>4%</td>
</tr>
<tr>
<td>600-640</td>
<td>793</td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>&lt; 600</td>
<td>587</td>
<td>1</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 14. Distribution of SAT Reasoning Scores (Math) for MIT Applicants 2011

While MIT accepts about three-quarters of their admits from the highest test score bin, they also opt to reject 85% of applicants in this top range, and instead offer admissions to students with slightly lower test scores, but that may offer other strengths. While IIT’s do not consider any candidate who fails to score in the top 5% of the JEE, MIT considers and accepts many candidates in lower parts of the distribution.

Moreover, since the MIT applicant pool is highly competitive (just as is the applicant pool for IIT’s), if MIT were to simply employ IIT's cut-off test score policy and only admit those 1700 candidates with the highest test scores, this would lead to admission of only those candidates who could score at or just below a perfect score. Several studies in the U.S. have shown that more men score in the upper tail of the distribution for competitive math tests: among the top 1% of scorers, there are 2 males for every female, and for those scoring a perfect 800 on the Math-SAT, MFR’s range from 6.58:1 to 8:1 (Ceci and Williams 2010). If this were the selection criteria used for MIT, admit gender ratios would be closer to 7:1 as opposed to 2:1. That is to say, if MIT and other U.S. institutions used the same hard test score admissions criteria for admissions as in India, then male-female ratios at U.S. top-tiered institutions would come close to the ratios we currently see in India's top-tiered institutions. This provides a strong indication that the ratio itself is a function of a very high discrete test score cutoff.

Marilee Jones, dean of admissions at MIT, has worked to raise the percentage of female admits to MIT’s programs. Since 1979 when she joined MIT, female admissions percentages have increased

33 http://web.mit.edu/ir/cds/2012/c.html
34 http://mitadmissions.org/blogs/entry/diversity-or-merit/
35 statistics found at http://mitadmissions.org/apply/process/stats
from 17% to 45%. Through this process, Jones has shifted MIT’s admissions policy on test scores. She admits that “she used to tell students and parents that MIT rejected lots of student with 800 SAT scores...She now tells students that they do not need score of 800 to get into MIT.”

A holistic admissions policy itself, which is less optimized on scores, may be a major contributing factor to better gender ratios for top tiered engineering institutions in the U.S. In trying to improve admissions policies, IIT’s have also vacillated between objective and subjective tests; however, they have not expanded admission criteria to consider other parameters that may be predictive of future success in engineering. Without consideration of these other parameters, capable (and potentially even better) candidates who just happen not to score in the top 5% of the test-taking pool are excluded from consideration for admissions to India’s top engineering programs.

2.4.3 Choosing the Right Selection Criteria
Given that we know the admissions policies are different for top tiered institutions in US and India, and lead to different gender ratios, we ask the question of which policy is better for the overall landscape of the engineering sector and what criteria can we use to judge which admissions process is better?

To answer this question, we must examine the end goal of selection criteria. For IIT’s, the goal certainly is to select the very highest quality candidate possible, and many would argue that it is the competitive nature and intense difficulty of the test that weeds out the very top candidates. On the other hand, many would ask how do we define “highest quality,” and how does the test recruit such candidates? Chris Patterson from MIT would define this candidate as one who is both prepared for the academic rigor of the MIT, and who can uniquely contribute to the community and learning environment of the school. The real question is whether a test alone, as the JEE is used in India, is sufficient to recruit the kind of high quality candidate that top-notch engineering colleges desire. Even intuitively, we can agree that a single score on Math, Physics and Chemistry is insufficient to identify all that goes into making a successful and brilliant engineer. To truly recruit the candidates who are likely to excel as the nation’s greatest innovators in engineering, institutions should consider personality traits such as conscientiousness, creativity, communication skills, people skills and much more.

At the very least, recruiting high quality candidates is about finding those students who have the highest likelihood of excelling in the engineering program. If we accept this as the end goal, then we should be using selection criteria that are most predictive of engineering CGPA. Hence, to know if the test is recruiting high quality candidates, one’s performance on the entrance exams should at least correlate with CGPA. If the JEE is truly an efficient instrument in recruiting the top quality candidates, then the highest scorers on the JEE should also be the students with the best CGPA’s.

Policymakers and researchers in the U.S. have done some investigations into this question, finding systematic gender differences in performance on the quantitative SAT for a number of reasons. The U.S. College Board (which designs and administers the SAT) has warned against relying on the results of a single instrument as well as the use of minimum test scores as admissions criteria. A study conducted by the College Board found no correlation between performance on the SAT and GPA. This study also showed that the quantitative section of the SAT has the greatest levels of over-prediction for males and under-prediction for females when assessing freshman year grade point

36 http://www.nytimes.com/2006/10/11/education/11FACE.html?_r=2&pagewanted=all
37 http://iitlife-rahul.blogspot.com/2012/06/iit-selection-criteria-changes.html
average (College Board 2008). Furthermore, another potential reason for gender differences in performance on the SAT is stereotype threat, a psychosocial mechanism that has been posited to interfere with female performance on tests administered in competitive environments. Stereotype threat has been found to account for up to 60% of the gender performance gap on the quantitative section of the SAT (Walton and Spencer 2009). Hence, the test itself and the environment that it fosters both systematically lead to the underassessment of female potential.

Studies conducted in the U.S. have also specifically found that using quantitative SAT cut off scores as admissions criteria unfairly exacerbates gender disparities in admit ratios. Males have been found to score higher on average than females and to have larger standard deviations that are pronounced in their quantitative scores, which “leads to even greater achievement gaps between the genders for higher ability students” (Nankervis 2011). While not all U.S. universities use test score cut offs, some still do. For example, the University of Texas Engineering Program specifies a minimum score of 600 in the quantitative section. Studies have shown that based on this elimination criterion alone, one out of every four males in Texas would be considered for admission, while only one out of every 7 females would be considered (Nankervis 2011). Hence the use of high cut off test scores acts as a main driver for high male to female ratios in admittance.

Similarly, IIT itself has recognized that there may be inefficiencies in the JEE as a predictor of future success in engineering programs. In 2005, a special task force led by top Prof. Idichandy of IIT Chennai, launched an internal study to assess the selection process based on data collected from all IITs. The study found that, while “there is a strong correlation between the marks of Classes X, XII and the CGPA during B-tech, there is little correlation between marks in Class X, Class XII and AIR (All India Rank in the JEE). [Further], there is little correlation between AIR and CGPA.”38 Hence, students who do well in school are highly likely to do well in B-tech program; however, being a good performer in school is not predictive of whether or not one will rank in the JEE. Further, being a topper in the JEE is not predictive of being at the top in a B-tech program. After this study, IIT’s dropped their initial screening test to enable students to be eligible to take the JEE, and instead deemed a Class XII percentage of 60 percent or above as an acceptable eligibility criteria for students to take the test.39

While the results of the study are not conclusive either way, they do question the validity of the JEE as an instrument with reliable predictive capacity. Further, the JEE format, which is quantitatively focused through testing Math, Physics and Chemistry, is likely to not only show the same problems with predictive capacity that the quantitative SAT has shown, but may also have the same problems with gender exclusion. Further, the highly competitive nature of the exam may put females at a disadvantaged if stereotype threat plays any role for Indian females. Hence, the use of a highly competitive cut-off score that accepts only the top 5% of candidates will only exacerbate any problems with gender imbalances that result from the design of the instrument.

These studies suggest not only that the selection process for IIT’s may lead to gender imbalance, but also may result in an incoming class that excludes some of the most capable candidates for the program. If the test systematically under predicts the success of females and over predicts the success of males, then a high cut-off test score criterion can lead to excluding capable females from consideration. Furthermore, since these imbalances are more pronounced in the upper-tail of score distributions, the more competitive the cut-off used, the more gender inequities will result.

39 Ibid.
We know that both the SAT and JEE as testing instruments are questionable in their ability to accurately predict the future success of candidates, and that these inaccuracies may also be linked to gender imbalances. In the U.S., we know that test validity is problematic – the quantitative SAT not only is limited in its ability to predict future success of candidate, but actually over predicts male success and under predicts female success. In India, we know that the IIT study at least failed to show that the JEE is indeed predictive of future CGPA in IIT programs.

Therefore, given that both the JEE and the SAT scores show limited correlation with candidates future success in engineering programs, there is no reason to rely solely on the predictive powers of these tests to identify the “highest quality” candidates for our nation’s top engineering colleges. Certainly these tests are pragmatic necessities, and should be used in the way that is most functional in the selection process. Nevertheless, for tests that show limited validity, the cut off should be lower to enable consideration of a wider pool of candidates, and other parameters should be used to reduce type 1 and type 2 errors. It is safe to conclude that the given little or no published evidence of test validity, a high cut-off is not warranted, which may be excluding meritorious students in general, but has become a larger impediment for females.

2.5 CONCLUSION AND RECOMMENDATIONS
The evidence and data available suggest that a few factors might contribute to the high MFRs we observe in India’s top-notch engineering institutions. There are moderate self-selection effects and there could be additional effects such as lack of coaching preparation available to aspiring female engineers. However, the most dominant and controllable barrier is the test itself and its function as the primary selection criterion for top-notch institutions. If the test itself and selection through high cut off test scores is not changed in any way, then the American lesson is that top-tiered engineering programs will remain stagnant with MFR’s of 7:1, or thereabouts, at best. As soon as the test and selection process are fixed, and ratios can begin to improve, then we should begin to see improvements in other factors such as self-selection and the perception of engineering as a prosperous career for India’s most capable females. In turn, the general confidence of young aspiring females, their parents and society will increase, and families will be more likely to invest in preparation for their female children to pursue engineering. While this may be an optimistic view, it is likely that changing the test not only will have the capacity to improve MFR’s immediately but also to start a virtuous cycle of positive feedback loops in other factors influencing the participation of India’s most capable females in engineering.

To make room for these women in India’s top engineering colleges, we recommend that IIT’s and other premier institutions expand their selection criteria to include other parameters besides test scores alone. Although U.S. top tiered admissions policies seem to be working within the U.S. context (or at least lead to greater gender balance), we recognize it may not work to simply project U.S. criteria on IIT’s admissions processes. We recognize that keeping objective selection criteria in India is aimed to mitigate corrupt practices that might emerge if criteria were more subjective. However, some of the selection criteria utilized in the U.S. can be employed if used in a way that is functional in the Indian context.

While some steps have already been taken in the new selection format for 2013, even this new format still leaves females systematically disadvantaged for entrance into the very top institutions. Consisting of a two-stage test process (a Main and Advanced test), the new JEE selection criteria
Women in Engineering: A comparative study of barriers across Nations

still requires those aspiring to attend premier institutions such as IITs and NITs to sit the Advanced exam and receive a top score for consideration.40

More steps can be taken to improve this selection process. For example, a larger test selection pool followed by interviews, as India's own IIM's use in the selection process, may enable candidates to show other skills besides the rote learning that is required in preparation for the JEE. Interviews may enable those candidates with a strong propensity for the creativity and innovation necessary for India's future engineers to stand out among a pool of candidates that otherwise would only be identified as a mere test score. Further, IIT's could also employ aspects of the School of Planning and Architecture application process, which uses a qualifying exam to identify a larger pool of candidates, who then gain admission based on a portfolio of previous work, statement of purpose and interview.41

Any of these steps will begin to open the door for more capable female candidates to receive the consideration they deserve. These improvements are not only a question of fairness, but also one of efficiency. Without making room for the wide range of talent available to India's engineering sector, India remains limited in its capacity for innovation. Hence, having more capable females in top-notch institutions can improve the health of India's engineering sector and the landscape of future innovation.

40http://jee.iitd.ac.in/faq2013.php
41http://www.spa.ac.in/gen_info.aspx
REFERENCES


Chen, Yanpei and Nam, Jooyeon. "Toward Gender Imbalance in UC Berkeley: Understanding and Rectifying Severe Gender Imbalances. UC Berkeley.


### APPENDIX

#### Appendix A. Self Perceived Rankings of Males and Females in Quantitative Ability

#### Engineering Males

<table>
<thead>
<tr>
<th>Self Perceived Rank Range</th>
<th>AMCAT Percentile Range</th>
<th>0-25</th>
<th>25-50</th>
<th>50-75</th>
<th>75-90</th>
<th>90-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>22.90%</td>
<td>20.97%</td>
<td>27.42%</td>
<td>19.03%</td>
<td>9.68%</td>
<td></td>
</tr>
<tr>
<td>Top 10%</td>
<td>31.61%</td>
<td>18.31%</td>
<td>27.69%</td>
<td>30.59%</td>
<td>37.29%</td>
<td>63.33%</td>
</tr>
<tr>
<td>Top 25%</td>
<td>23.87%</td>
<td>29.58%</td>
<td>20.00%</td>
<td>29.41%</td>
<td>18.64%</td>
<td>13.33%</td>
</tr>
<tr>
<td>Top 50%</td>
<td>21.29%</td>
<td>30.99%</td>
<td>30.77%</td>
<td>15.29%</td>
<td>16.95%</td>
<td>3.33%</td>
</tr>
<tr>
<td>Top 75%</td>
<td>18.39%</td>
<td>16.90%</td>
<td>16.92%</td>
<td>21.18%</td>
<td>20.34%</td>
<td>13.33%</td>
</tr>
<tr>
<td>Top 100%</td>
<td>4.84%</td>
<td>4.23%</td>
<td>4.62%</td>
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<td>6.78%</td>
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</table>

#### Engineering Females

<table>
<thead>
<tr>
<th>Self Perceived Rank Range</th>
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<th>0-25</th>
<th>25-50</th>
<th>50-75</th>
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<tr>
<td>Percent Sample</td>
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<td></td>
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<tr>
<td></td>
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</tr>
<tr>
<td>Top 10%</td>
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<td>20.25%</td>
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<tr>
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<tr>
<td>Top 100%</td>
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</table>

#### Non-Engineering Males

<table>
<thead>
<tr>
<th>Self Perceived Rank Range</th>
<th>AMCAT Percentile Range</th>
<th>0-25</th>
<th>25-50</th>
<th>50-75</th>
<th>75-90</th>
<th>90-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Top 50%</td>
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</tr>
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<td>6.45%</td>
<td>5.04%</td>
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</table>
Non-Engineering Females

<table>
<thead>
<tr>
<th>Self Perceived Rank Range</th>
<th>AMCAT Percentile Range</th>
<th>0-25</th>
<th>25-50</th>
<th>50-75</th>
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</tr>
</thead>
<tbody>
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<td>25.03%</td>
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<td>24.24%</td>
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<td>30.68%</td>
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<tr>
<td>Top 25%</td>
<td>14.62%</td>
<td>14.43%</td>
<td>19.91%</td>
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<td>10.23%</td>
<td>13.33%</td>
</tr>
<tr>
<td>Top 50%</td>
<td>23.24%</td>
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<td>25.54%</td>
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<tr>
<td>Top 75%</td>
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<tr>
<td>Top 100%</td>
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<td>8.46%</td>
<td>7.79%</td>
<td>7.56%</td>
<td>5.11%</td>
<td>5.71%</td>
</tr>
</tbody>
</table>

Appendix B. Title IX of the Educational Amendments of 1972

The United States legislation Title IX of the Educational Amendments of 1972 has played an influential role in increasing the opportunities and participation of females in all forms of education from kindergarten through graduate level in the U.S. Title IX's primary goal was to eliminate gender discrimination of all forms taking place at higher education institutions. The original legislation reads:

“No person in the United States shall, on the basis of sex, be excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving federal financial assistance.”

While Title IX has a relatively broad scope, it has played a major influence on women's participation in engineering programs. Over the last 40 years, the % of degrees conferred to females increased from 40% to 58%, but this same statistic in engineering degrees has increased from less than 1% in the 70's to 19% in current times.

As the focus on women's participation in engineering has grown, a number of women's interest groups and university programs have developed to encourage the recruitment and mentorship of young capable females in engineering. These include:

- The Society of Women's Engineers est. 1950 which facilitates volunteering opportunities and sponsors local events to connect pre-college girls with engineering opportunities and mentors, provides college scholarships for aspiring engineers, and provide resources such as an Engineering Guide for Middle and High School girl, various after school programs, engineering competitions, curriculum standards, and career counseling.42
- The Association for Women in Sciences,43 est. 1971, which provides advocacy and mentoring and generates policy reports on the state of female participation in the sciences
- Women in Engineering (WEI) initiatives on college campuses target the increasing enrollment and retention of women in science and engineering undergraduate programs.

Appendix C. Female Participation in Coaching Institutions

Some preliminary research has been done to look at female representation in coaching institutes in India. In 2010, an informal survey was conducted with three of India's well-known engineering

42 http://societyofwomenengineers.swe.org/
43 http://www.awis.org/
entrance coaching institutes in 6 cities across India (Singh and Patak 2010). The results are reproduced in the table below.

**Gender representation in 3 coaching institutes across 6 cities**

<table>
<thead>
<tr>
<th>City</th>
<th>Total Students</th>
<th>Female (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaipur</td>
<td>887</td>
<td>24</td>
</tr>
<tr>
<td>Mumbai</td>
<td>1101</td>
<td>17</td>
</tr>
<tr>
<td>Delhi</td>
<td>4500</td>
<td>24</td>
</tr>
<tr>
<td>Hyderabad</td>
<td>8000</td>
<td>23</td>
</tr>
<tr>
<td>Tirupathi</td>
<td>134</td>
<td>23</td>
</tr>
</tbody>
</table>

While these data suggest that disproportionately more males are receiving coaching preparation for entrance exams in engineering schools, this tells us little about reasons why this might be happening or how many females relative to males are making it to the top tiered colleges. To understand this dynamic further, we conducted some qualitative research through in-depth interviews with current students at India’s top engineering colleges.

**Interviews with IIT girls**

In our in-depth interviews with students, we also spoke to a small sample of current students attending India’s top engineering institutions (n=24), including a group from IIT’s (n=12), with an even distribution of males and females. We asked IIT females directly why they thought gender ratios at the top institutions were so imbalanced. All 6 females interviewed from IIT’s cited hesitancy of parents to send their daughters to far away coaching institutes, or to invest in this additional educational expense. All of the female IIT students had undergone coaching to clear the JEE, and many spoke of friends who were not allowed to attend coaching and were unable to clear the JEE. Although only anecdotal, this evidence suggests an underlying trend in parental hesitancy to give capable females the same level of preparation necessary to clear the JEE. Reasons can vary from fear of safety for sending females far away to top coaching institutes, to son preference connected to unwillingness to make the financial investment in daughters’ education.

To follow up on these data, we surveyed our entire sample through an email blast on questions surrounding parental hesitancy to send children to coaching institutes or far away to colleges. While the data did not show any significant differences between males and females that can offer conclusive evidence, we believe this is an important area for future research. If high-performing capable female talent are truly not receiving the same level of preparation as males for the entrance exams to India’s top-tiered institutions, this could explain at least some of the gender disparity in clearing rates for the JEE.
CONCLUSION

The two investigations within this report offer some insights into the nature of on the “leaky pipeline” for aspiring female engineers in India.

In our comparison of trends for women in engineering colleges in India and the United States, we conclude with confidence that in-college environmental barriers for female engineers in India do not exist as they do in the United States. However, there is some evidence that pre-college barriers exist through lack of academic preparation or underestimated self-perception of ability. While the college level itself does not present as a point of leaks for female engineers, significant leakage may be occurring for aspiring females before even reaching college.

Our investigation into top-tiered institutions in India and the U.S. show that while there is moderate self-selection for India’s top females, the primary contributor to the high male-female ratios is India’s premier engineering colleges is the use of high discrete cut off test scores in the selection process. While admissions criteria should be identifying those candidates that are most likely to succeed as future innovators of the Indian engineering sector, it is likely that the current system is excluding a large portion of female talent.

Hence, to better understand how the “leaky pipeline” functions in India, future research should look with more detail into pre-college barriers for aspiring female engineers. Such research should focus on what is happening with the female population that does not make it into engineering colleges, specifically those receiving an all-rural or all-government education, who have uneducated parents or who grew up resource poor. Additional research on the predictive capacity of the JEE and the degree to which is leaves capable females systematically disadvantaged is also needed. It is likely that undiscovered female talent exists in many places that are missed by the current system.

These findings provide us with some insight into engineering as a face of gender in India. In relation to Kapoor’s “two Indias,” we see a mix in trends that suggests a straddling of these two worlds. The growing participation of women in engineering colleges and the positive steps in the institutional environment for women within B-tech programs is a sign that the engineering sector has the potential to be a place of great opportunity for women. However, the pre-college exclusion of certain types of women is a sure sign that women still remain left out from equal opportunity. Without an effective process for identifying capable female talent from all backgrounds, India’s engineering sector remains limited in its capacity for innovation. Greater and more diverse female representation in engineering colleges may offer even greater prospects for growth in the Indian economy.