Forms of Social Asymmetry and Cultural Bias: Of Gender and Science in India and the World

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Studies on women in science in any part of the world do not fail to note that there are very few women in science and technology fields, especially, at the higher levels. The common trend is a thinning out of numbers as we go up the organizational hierarchy with the least number of women among full professors, deans, directors and president/vice chancellors. Studies from different parts of the world do show how women's upward mobility in the organisation, attaining positions of leadership and winning awards and patents for innovation meet with multiple constraints requiring them to work twice as hard to reach any level; in some places the barriers are harsh so as to cause stagnation in their career. In the feminist scholarship in the US, this is referred to as the 'glass ceiling effect', some kind of a non-visible block or obstruction that does not allow them to reach higher levels in the academic organization (David and Woodward 1998). 'Glass ceiling effect' locates the problem in the organization of science and technology in which soft variables like discrimination against women based on biases about their cognitive abilities to do hard science play a role in procedures of recruitment, promotion and selection for awards. Alternatively referred to as 'hierarchical segregation' and 'leakage in the career pipeline', this trend clearly shows that there is a huge gap between numbers of women enrolling for science and technology courses and the numbers who make it to the top (Schiebinger 1999). There is also horizontal segregation, namely, the absence of women in certain fields like technology based entrepreneurship or in certain disciplines like mathematics and geology.

This pattern of lower proportion of women in apex positions in science and technology fields is more or less found in most parts of the world, reflecting deep rooted and gendered social asymmetries in academic institutions. This is also a profusely researched theme and numerous studies highlight aspects of organizational practices that hinder women scientists in attaining higher professional levels. Public sector and government funded science seem to show slightly greater inclusion of women than industry funded science (European Commission 2008). In fact the number of women in top positions is inversely proportional to the magnitude of funding, with a larger proportion of women concentrated in poorly funded projects (ibid). A series of related factors such as the predominance of men in decision-making committees, male-centric work environments (Case and Richley 2013) that place a premium on heroic and individualistic achievements rather than institutional work (Rapoport et al 2002, Dean and Fleckenstein 2007); male scientists engaging in academic activities that give national and international visibility as opposed to women who focus on academic responsibilities like teaching and supervision of research that are invisible (Chanana 2003); the significance of informal networks and cliques in securing opportunities within organization and the biased decision making in funding allocation and in promotions (European Commission 2008) have been discussed in this context.

High attrition rates for women in science and technology careers is a trend noted by scholars in India as well, but there is a major difference in the level at which the numbers fall. Notwithstanding national differences in the organization of higher education, statistics of women's entry and progress in science and technology fields in countries like India and Brazil seems to be equal to or, better than countries in the global north at all levels. This is true of Italy, Spain and some east European countries as well, though absolute numbers may not be high. In other words, there are lesser women in apex positions in the science and technology sector throughout the world, but their dropout rate at higher levels is much lower in certain countries of the global south. In fact, we do not find the 'leaky pipeline' or the exit of women as we move up the organizational hierarchy, in countries like India as the stagnation occurs at a much later stage.

What is even more puzzling is the fact that the countries that have progressive policies and grant the most civil liberties to women such as the US, Sweden, Netherlands and Germany have much lower participation of women in science and technology than the EU average. A linear understanding of the women's question in science that prioritises the experience of the industrially advanced countries is therefore inadequate to grapple with the dynamics of gender asymmetry in science institutions across the world because gender asymmetry is maximum in the industrially and scientifically most advanced parts of the world.

Secondly, the pattern of gender asymmetry, the institutional domain in which it is located and the cultural values and the self perception of the women scientists vary in societies like India from that of the industrially advanced rich nations. Terms like 'glass ceiling effect' may not help unravel the different cultural moorings of bias against women as they focus only on organizational factors.

Gender differentials in scientific careers may be a social fact but the barrier to women's professional advancement in science need not be the same everywhere. So we have to ask: Is the pattern of women's career movement same in different countries? Are gender specific barriers located only in the organizations? What is the source of bias against women in science? Are they similar everywhere? What is the explanatory potential of concepts like 'glass ceiling effect'?

It is the argument of this paper that the cultural roots of bias against women are different in India and that it is reflected both in the pattern and dynamics of gender asymmetries and in the self perception of women scientists. First, the level at which women's participation declines varies between countries indicating that the dynamics of asymmetry are not the same. Women's participation and progress in scientific careers seems to be better in regions with family centered culture than in countries with progressive rights based policies for women. Second, the cultural barriers to women's scientific career are not the same throughout the world; in scientifically advanced countries, science itself, i.e., biological and genetic theories of cognitive ability is often the source of prejudice against women as to be able to retard or diminish the beneficial effect of civil liberties and progressive policies, while commitment to familial values and solidarity is the primary deterrent in the others.

In order to set out these issues, I provide a brief overview of data from studies on women in science in other parts of the world in the first part of the paper, followed by a focused discussion on the Indian situation in the latter.

Women in Science - Far Behind in the Advanced World

The shocking fact is that for several decades, women's participation in science and progress in scientific careers has been abysmally low in the highly industrialised countries with an advanced science and technology sector such as those of central Europe and North America.

At France's National centre for Scientific Research (CNRS) which runs about 1300 laboratories in the country, 31.2 percent of the researchers were women in 2004. The interesting thing is that unlike the experience of countries seeing rapid growth in women's participation in science and technology, the percentage of women researchers has remained constant at 30 percent ever since the inception of CNRS in 1946 (de Cheveigne 2009). Though French law prohibits discrimination on the basis of gender, the invisible barrier to women's career development in the French system is reflected in the fact that the organisational mobility of both women administrative staff and women scientists is very low. In 2000, there were 9 percent of women in theoretical physics, 29 percent in catalytic chemistry and 53 percent in social anthropology. The 'glass ceiling effect' is reflected in the fact that even in social anthropology where women are greater in number they are not in higher positions. So de Cheveigne (2009) argues that the 'critical mass' theory that suggests that increased recruitment of women into organisations will automatically lead to their upward organisational mobility is not borne out in this case.

The situation is not any better in Germany. Compared to other EU countries, the German academic community is considered to be 'one of the most male-dominated' (Fuchs, Stebut and Allmendinger 2001; 177). The ratio of women students is the lowest; besides enrolment of women students in any field remained around 30 percent till the 1990s after which it increased very slowly. In some fields their numbers were dropping. In mathematics and natural sciences, 17 percent of the student population were women in the 1970s but this has fallen to 12 percent today. In engineering the number had however doubled to reach 7.3 percent in 1990s. A study at the Max Planck Institute in 1999 showed that only 11.3 percent of the researchers were women even after decades of 'target group programmes' to improve women's entry into science and technology (ibid). The UK has a better record in this regard. It had 30 percent and 48 percent of women in doctoral degrees in chemistry and biology in the year 2000 (Bal 2004).

In the European Union only 9 percent of women hold top research positions in any field despite the fact that they constitute 50 percent of first degree students in the universities. Women constituted only 6 percent of full professors in any field in 1998. Though a large proportion of women, namely, 14 percent of them were full professors in the cultural sciences, Fuchs, Stebut and Allmendinger (2001) think that women are generally underrepresented in higher academic positions in any field in Germany, including the field of medicine with just 6 percent of women full professors; this is unlike other countries within Europe. In fact, the gap between women enrolled at the graduate level and those who make it to the highest level of full professorship is quite large in Germany and has not changed significantly in the past decades (Fuchs, Stebut and Allmendinger 2001).

Women earn 50 percent of science graduate degrees in the US and 31 percent of doctorate degrees, but only 115 are full professors. Only 3 women were Deans in the 311 engineering colleges in the US in 1995. There is also territorial segregation in disciplines such that there were only 9 percent girls in physics courses as late as 1995. Only in 1989 did Harvard University have its first tenured woman faculty in chemistry. The website of the Institute of Physics (US) says that 50 percent of its women members are part-time researchers as opposed to 3.5 percent of men[1]. In MIT, reports say that women scientists had consistently lesser lab and office space. In the UK there was only one full professor of Chemistry in 2002. Further in countries like the US where salaries are negotiated, women's salary in the same post was lesser by 15-17percent than that of men. Interestingly, Asian women engineers drew higher pay in the US, than American women engineers. In general it is felt that American women quit science and technology in early career than stay back and fight (Schiebinger 1999).

In the European Union, a study in 2003 showed that there were 34 percent women with PhD in science and technology subjects but only 9 percent had full professorship[2]. In Germany only 2 percent women were found in senior faculty position in five key science disciplines; Max Planck institutes had only 2 percent women scientists[3] (Schiebinger 1999). Japan also has a very low participation of women in science and technology.

[1]Institute of Physics, US: www.iop.org/publications
[2]http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2009_02_27/caredit.a0900030
[3]http://ec.europa.eu/research/science-society/pdf/she_figures_2006_en.pdf

Feminists in the west have engaged insightfully with questions about scientific productivity and the kind of research writing done by women scientists in comparison to their male counterparts. Schiebinger's literature survey shows that women scientists in the US had lower productivity, lesser citation rates and tendency for self deletion from career (Cole and Zuckerman 1987). Cole and Zuckerman concluded that the 'social change wrought by the women's movement and affirmative action had done nothing to change women's overall productivity'. Men at prestigious institutions published 5 or more papers per year and 22 percent women compared to 11percent men had not published even one scientific article 12 years after their PhD. They also showed that the women's productivity was not affected by marriage and that women scientists married to scientists published 40percent more than those married to other men proving that they drew upon husbands contacts.

By way of countering the observations of Cole and Zuckerman, Schiebinger cites Long's research on women's publications. She showed that benefits for women's productivity after marriage had to do with the fact that women's mentors, 80percent of whom were men, felt comfortable collaborating with married women fearing rumours about affairs. Feminist writers in the US thus problematised the notion of productivity and showed how it was linked to social perceptions. Long also noted that men's citation rates were higher as they published more papers, But if we consider paper for paper, women were cited almost the same or better than men (5.02 citations for women as against 4.92 for men in 1984). In biochemistry, women's research carried more impact. Studies in the US pointed to the fact that women had different standards for publication, namely, thorough and comprehensive research, while fewer men characterized their publications this way. It seemed that women's work focused more on exhaustive coverage of the subject and were less strategic in their approach (Schiebinger 1999)

The more recent report of the European Commission (2008) notes an increase in the enrollment of women students in science courses and a modest increase in the average percentage of women in professorial positions to 10-15% in the member states, but that does not translate into women reaching higher positions. In UK for instance, a study notes that while 60% of the medical students are women, 88% of the full professors in medical schools are men. Lack of role models and workforce practices are cited as reasons for this conspicuous gap between enrollment and upward mobility of women (European Commission report 2008;20). In Belgium with 55% of women PhD holders, only about 15% have reached professor's position and the representation of women in research councils is 7%. In France the proportion of women presidents of scientific evaluation committees went up to 15% in 2002 and has been stagnant since and the discouraging factor is that 'the conscience of a gender problem is missing in France' (Ibid. 48)

For several decades these well documented facts have been analysed by feminist philosophers who examined not just the presence of women in science, but critically investigated the very epistemological and ontological foundations of modern science and its nexus with capitalism (Harding 1991, Keller 1996). Social scientists and policy planners have also tried to address some issues time and again. The interesting fact that a higher proportion of women may be found in scientific and technological fields in those places where women do not enjoy liberties as their counter-parts in Western Europe. For example, in Central and South American countries the proportion of women studying science, engineering and medicine was higher than in Western Europe (Leta and Lewison 2003). Within the field of natural sciences, there were 1.2 male students for every female. The figures for students in higher education in the 1983 UNESCO statistical yearbook revealed that there was very little difference in the proportion of women in relation to men studying science, mathematics and medicine in Malaysia and the United Kingdom. But in the field of engineering there was a marked difference in favour of Malaysia, with women comprising only 4.6 percent of all students of engineering at an advanced level in the United Kingdom, compared to 12.4 percent in Malaysia. The latter is a country with a strong Muslim tradition, and in which women's status in relation to that of men is not more advanced than in the United Kingdom (Elliott and Powell 1987).

In fact, Catholic countries such as Italy and Portugal where extended family support is available to women professionals and former socialist countries like Latvia and Lithuania have nearly 40 percent participation of women. Latin American countries, specifically, Brazil, shows a high degree of women's presence in the federal science and technology sector.[4]

Another crucial observation is that in general there are fewer women in highest positions in all disciplines in Europe and North America, not just in science. Though the entry rate of women in the humanities and social sciences is higher in Western Europe, the proportion of women reaching apex positions in humanities and social sciences is also lower than equal opportunities in these countries would permit (Plonski and Saidel 2001).

Linear and rights based understanding of women's situation based on individualism /liberalism fail to explain why liberalism did not enable greater women's participation in science. If feminist struggles, civil rights and progressive state policies have not translated into women's presence in top science and technology sectors both in liberal social settings as the US and in socialist settings like Sweden, the bias behind the 'glass ceiling effect' requires greater attention because the term gives no clue about biases against women produced by science itself . How scientific theories could be the source of bias would be better understood if we consider the contrasting case of India.

The Indian Situation

India for all its patrifocality is not very much behind in enrollment and permanent positions of women in science and technology. There were 38 women for every 100 men in higher education in the late eighties (Desai and Krishnaraj 1987 c.f Subrahmanyan 1998). Women have reached about 31-31percent at all levels of the hierarchy in science education, namely, undergraduate, post graduate and Doctoral degree in science and technology subjects. It is found that the discontinuance in higher education is equal among men and women in India (ibid). However, there are fewer women full professors and heads of department in the science and technology departments and among Bhatnagar[5] awardees. So it seems that women's scientific career reaches stagnation at a higher level than in Europe and North America.

The point is not that there is no issue in India about women in science, but the level where the asymmetry is to be found and the factors involved suggest that the dynamics here is different. What then are the factors associated with women's entry and stabilization in science and technology sectors? Let us look at the situation in India by examining the literature available on each level from enrollment to higher organizational positions.

Enrollment

In India, the enrollment of women in graduate programmes in the pure sciences has steadily gone up from 7.1 percent in 1950-51 to 34.17 in 1997-97 (Gupta and Sharma 2003) and 40 percent in 2009 (Chandra, Godbole et al 2008). The number of women in the science and technology courses at the Masters level is 43 percent and at PhD level is 37 percent. This shows that the proportion of women getting into higher science education is quite high in India (Chandra, Godbole et al 2008). Women in science degrees has tripled from 1950-51 to 1980-81 whereas arts numbers have

[4]http://www.iadb.org/en/news/webstories/2007-01-16/women-on-the-challenges-of-being-a-scientist-in-latin-america-and-the-caribbean,3564.html

[5]The Shanti Swarup Bhatnagar Prize for Science and Technology (SSB) is an award in India is given annually by the Council for Scientific and Industrial Research (CSIR), Government of India, for outstanding research, applied or fundamental, in biology, chemistry, environmental science, engineering, mathematics, medicine and Physics.

doubled though arts has more absolute numbers (Mukhopadhyay 1994). The enrollment of women in science and technology courses in some federal states is impressive: 65 percent in Kerala, 55 percent in Punjab and 50 percent in Tamil Nadu; the lowest in women's enrollment is 20 percent in Bihar and UP (Duraiswamy and Duraiswamy 2009). In the US only 16 percent of the engineering class consisted of women in 2005[6]. In India women engineers constituted around 37 percent in the states of Kerala, Tamil Nadu and Maharashtra in 1998 with large numbers in electronics followed by civil and electrical engineering (Parikh and Sukhatme 2002). As engineering courses are stepping stones for upward social mobility, a fair share of girls from the depressed sections is entering undergraduate courses in science and technology due to policies of affirmative action.

A study at the Indian Institute of Technology[7] (IIT) at Madras, shows that during the five year period 1983 to 88, the percentage of women gone up marginally from 6.91-8.02 in bachelor course in engineering and from 2.33–3.31 in bachelors course in technology (Mukhopadyay 1994). However the numbers were lower in technology courses, while the numbers in PhDs are constant showing greater preference for pure science careers among women at the IITs. The Joint Entrance Examination (JEE) Report shows that 11 percent women cleared the JEE in 2012; this is markedly higher than the previous decade. A comparative study of women in engineering in India and the US[8] conducted in 2012 shows that the number of women appearing for the JEE has gone up, but the female clearing rate for JEE has not increased significantly from 2005. It remains around 1.90 percent while male clearing rate is 6 percent. However, the survey reveals that with the exception of the IITs, the Male Female Ratio in engineering courses in India is 1.96, while the ratio of male to female students in engineering is as high as 4.61 percent in the U.S.

Currently enrollment of girls in higher education is greater than that of boys in many regions, but in the absence of similar growth rate in female literacy, it may be gleaned that those who are already into the education system are now opting for higher education. The social base of women entering higher science and technology education hence could remain narrow (Subrahmanyan 1998). At the same time, this shows that those women who do enter higher education chose science and technology subjects more and more. In Australia as in India, women go for higher education in greater numbers but their participation in the labour market is not very high.

These figures are comparable to those of Brazil where women's presence in science and technology is quite impressive. Among the Latin American countries Brazil has the largest science and technology sector on which it spends 1.24 percent of its GDP. U.S spends 2.54 percent for science and technology, while Canada spends 1.59 percent of its GDP (Plonski and Saidel 2001). Most of the science and technology happens in the higher education system in Brazil rather than in industry and men are found in greater proportion in the private sector. Women were responsible for 54 percent of the enrolment in higher education in Brazil. The national average for the proportion of women researchers was 42 percent in the 1990s; in engineering they constitute 20 percent and in the hard sciences they comprise of 30 percent of researchers. Overall average of women's participation in all science and technology fields and activities was around 30 percent - 30.5 percent of federal research grants, 27.3 percent of academic papers published abroad, 30 percent of academic books, 32.5 percent of academic papers presented. Their presence in academic evaluation bodies however, was only 17. At the federal University of Rio de Janeiro, there were 67 percent students in chemistry and 19 percent students in Physics in 1990 (Plonski and Saidel 2001).

Another curious fact is about the trends in enrollment and upward mobility of women in

[6] European platform for women scientists: http://home.epws.org/filter/data/A-note-on-girls-in-science-US-data

[7] Indian Institutes of Technology (IITs) are prestigious group of public engineering and management institutes in India regarded as institutions of national importance entry to which is by the Joint Entrance Examination (JEE)

[8] Aspiring Minds survey on 'Women in engineering: A comparative study of barriers across nations' conducted in 2012: https://www.aspiringminds.in/docs/women_in_engineering_a_comparative_study_of_barriers_across_nations.pdf

science and technology over a period of time. Enrollment of women in science and technology subjects have gone up rapidly in the past 2-3 decades in countries like Brazil and India with a doubling of enrollment in Brazil, while in the global north, the enrolment of women has not increased significantly since 70s and eighties. In the past decade conscious effort by the European Union to encourage women to enter science has improved the situation marginally but there is resistance that gender equality could dilute the standards of excellence in premier institutions (European Commission Report 2008).

Doctoral Degree and Professorship

While enrollment figures for women at entry point are high, there is huge shortfall at penultimate positions in science and this is equivalent for almost all countries in the world[9]. But the level at which the drop occurs is varies under different institutional settings and this lends a clue to differing mechanisms of gender asymmetry.

India was better in this respect in that it had 10 percent faculty positions and 3 percent full professorship in Physics held by women in 2002[10]; in the Indian settings however salaries are not negotiated in the higher education sector. Even in the early nineties, Madras University, showed greater number of women in post graduate science courses than men, which is maintained in MPhil and falls in PhD showing that women quit after their MPhil degree and settle for lower posts. This is also true of the biological and medical sciences. On the whole, in Madras University there were 40-41 men each in all 3 positions - lecturer, reader and professor, but only 15 -16 women in junior positions and 8 among professors. It is important to note that while there were few women faculty from the Backward Castes, there were no SC and Muslim women faculty at the higher levels (Subrahmanyan 1998). We find the absence of women from the depressed sections as we go up the organizational hierarchy.

Bal's study (2004) of biologists in various national institutes in India shows that women form 20-31 percent of the faculty in the life sciences as a whole. This, she notes, is a fall from their proportion in doctoral degrees. The proportion of women biologists in senior positions in various institutes and central university departments varies between 7.7 to 25.3 percent. In junior faculty level however, there were more women. For instance, in 3 out of 8 national laboratories, women constituted 34, 37 and 56 percent of lecturers and readers respectively, indicating that the younger generation of women may be entering in larger measure as permanent faculty.

But the social base of women making it to the higher levels in the science and technology fields is very narrow in India as in other countries. A larger proportion of Backward Caste and Scheduled Caste[11] women candidates who enter professional science and technology graduate courses do not seem to go for post graduate education, instead, take up jobs after graduation. Most of the women in research and teaching in science and technology fields are from higher caste and class background. We may infer from this that a proportion of women from the lower echelons may be entering the job market in the private and government agencies in the science and technology sector, while those from the higher social sections may be located in research and teaching. The intergenerational mobility in both classes however, is great and in itself warrants a separate study.

[9] http://www.iiap.res.in/personnel/pshastri/GenderEquity/Women_Gupte/node2.html
[10] http://www.iiap.res.in/personnel/pshastri/GenderEquity/Women_Gupte/node2.html
[11] Backward caste refers to communities listed by the government of India as having been socially backward and hence lacking in access to opportunities. Scheduled Caste refers to those communities listed by the government as having suffered the discrimination caused by segregation and untouchability. These communities have been offered reservation in education and employment by the Indian government to make up for the historical loss in cultural capital and social esteem.

If we look at the highest funded institutions by the Department of Science and technology (DST), namely, the Defence Research and Development Organization, and the Department of Atomic Energy, 21 percent, 10 percent, and 17 percent of scientists were women in 2008, respectively. In the Indian Institute of Science only 7 percent of faculty members were women including faculty in biology, where typically the percentage of women is higher than in physics. The percentages of fellows who were women in the three major scientific academies in India - the National Academy of Sciences, the Indian National Science Academy, and the Indian Academy of Sciences (IAS) was 6 percent, 4 percent, and 5 percent. Fewer than 10 women were fellows of all three (Chandra, Godbole et al 2009).

While the proportion of women at apex positions is indeed low in India, the remarkable fact is that the drop out does not occur right through the career but mostly after the post doctoral level. It does not seem to be the case of a 'leaky pipeline,' because a third of women seem to reach up to postdoctoral level and secure permanent positions in science and technology fields. The pattern of women's upward mobility in India is an 'ascending spiral movement indicating career choices which are upward in direction but slowly paced with long horizontal stop over's' (Gupta and Sharma 2003)

We get the cue from the writings of women physicists themselves: 'Two scenarios could account for these facts: one is that the situation is improving as a function of time, so that there are few senior women scientists but several women students of science. The other possible scenario is that, in contrast to many Western countries where there is a "leaky pipeline" and the percentage of women drops steadily at every stage, the situation in India is different: up to the doctoral degree, there are a significant number of women in science, but there is a precipitous drop at the postdoctoral level. Both surveys and anecdotal evidence suggest that, unfortunately, in India it is the latter situation that prevails: we have not a leaky pipeline but a catastrophic postdoctoral out flux! This is largely due to societal pressure on these women to give up their careers for marriage and motherhood, though discrimination in hiring and other practices cannot be ruled out' (Chandra, Godbole et al 2009; 120). A recent survey[12] (2012) on 'Women in engineering' in India and the US also corroborates this point that there is no 'leaky pipeline' in India for women engineers because their dropout rate is almost zero, while there is a huge gap between admitted and completed students in the US.

The picture is similar in Brazil for which we have some data : 21 percent of the women faculty at the University of Costa Rica were in the department of industrial engineering, 27 percent in architecture and 38 percent in computer science. Five out of 13 deanships were held by women while they were directors in 10 departments out of 41. The increase in the number of women in higher positions seems to have occurred since the late seventies (Twombly 1998). At the University of Sao Paulo, a discipline like engineering had 26 percent of women at the graduate level and 9 percent of women at the faculty level (Plonski and Saidel 2001). About 5 percent of the women became full professors in Brazil, 'in contrast to 19 percent of their male counterparts', but Plonski and Saidel (2001; 224) argue that this is not bad in comparison with other countries. They point out that in Germany only 2 percent of the women in the natural sciences get to the top of the ladder and in the USA the proportion of women full professors is 5 percent in biology, mathematics, chemistry and physics. In Great Britain, the authors show that only 1.3 percent women were full professors in the sciences in contrast to 12percent of the men. But women in Brazil earned lesser than men on the whole; 6 percent earned more than US $ 25000 while 16 percent of the men earned more than this amount; men were concentrated the in private sector jobs, while women were in the federally funded institutions (Plonski and Saidel 2001).

Brazilian science however owes much to the Jewish refugees from Hitler's Germany. Accom-

[12] Aspiring Minds survey on 'Women in engineering: A comparative study of barriers across nations' conducted in 2012: https://www.aspiringminds.in/docs/women_in_engineering_a_comparative_study_of_barriers_across_nations.pdf

plished scientists mostly men, migrated to Brazil during the 1930s and their educated wives also made careers for themselves here. Plonski and Saidel present cases of renowned women scientists in the first part of the twentieth century in Brazil and we find that a significant number of them were Jewish women from highly educated families from Germany and central Europe, though there were Brazilian women as well. The next generation of Brazilian women in science and technology however were not from very highly placed background. In the seventies the federal funding for higher education in Brazil was hiked and this improved funding saw the rise in both enrolment of women in science and technology as well as the rise in the percentage in the faculty since the seventies.

Productivity among Women Scientists in India

Subrahmanyan's (1998) estimate of women scientist's productivity in Madras University shows 1.3 publications per year/ per person which is same as the average publication of women scientists in state universities in the US. There were more publications in biological sciences than physical and mathematical sciences. Studies in the eighties (Chakravarty 1986) found that about 50 percent of the women scientist's research in India had lesser analytical content and had more of collection and review elements; hence they did not come in the ambit of patents and innovative experiments.

Bals study (2004) of women biologists also includes a careful scrutiny of 56 international journals rated as top 5 percent in the field of biology. The survey revealed that Indian authors of Indian origin published in about 41 of them. 14.5 percent of the 669 papers in the past decade were written by women. Bal (2004; 3651) opines that the 'high- quality productivity of women biologists is not 'commensurate with their proportion of representation in employment'

Recent investigations such as Neelam Kumar's study (2009) of 117 scientists (56 women and 61 men) from 8 institutions in the country, report that there is no significant difference in the quantity and quality of women's publications and in certain fields women are equal to men. Yet there are only 8 women out of 333 who received the Bhatnagar award and only 34 women are there among 835 fellows in the Indian Academy of Sciences.

Kumar (2009) finds that equally productive women in the same field as men do not achieve higher academic rank and women were not found in editorial boards and professional networks. If we considered the number and kind of publications, the study found that women published more in international journals than men, that there was no difference between women with family and children and those without in productivity, that at the middle level the women were in fact more productive than men in the same field and that the impact of their publications in the field was greater according to scientometric data. Yet they were not found in higher positions in the institutions. They were not recipients of awards and were not visible in professional bodies as editorial boards. The author argues that the probability of attaining higher ranks was determined more by gender than productivity. Studies also note that male mentors in Indian institutions were condescending towards women researchers and often reproduced the hierarchies of family relations at the work place (Subramanian 2007)

The studies note in general that women scientists were not able to formulate and execute research programmes, to create networks and get able mentors; there was greater preoccupation with familial concerns.

How do we understand the relatively better participation of women in science in societies with patrifocal and family centred values while it is low in societies with liberal and progressive policies?

Gender Discrimination: Differing Dynamics and Logic

In the US, a major barrier for women scientists aspiring to achieve high positions in science and technology institutions is the doubt about their cognitive ability to do science. Biological, neurological and psychological experiments have tried to arrive at the basis of mental abilities of men and women in several ways. The shape and size of the skull was used as a measure of brains size (craniometry) which determined intelligence, moral behavior and female brains were found to be small and hence incapable of higher order intelligence. Though craniometry is discredited today, studies on genetic codes have carried forward some of the biases emerging from science proper. Besides large number of psychometric and anthropometric tests were conducted in the past century show differing cognitive abilities of men and women. In classical theory of reproduction, women provided the matter while men provided the form already perfect in the semen. Reductionist biology has led to isolation of single parameters of cognitive abilities of comprehension and computation. It is not surprising to hear Nobel laureates drawing upon such studies and expressing their views in public on weak mathematical aptitude of women.

This then is a clear case of bias generated by science itself. It also shows how insular surveys and statistical measurements could be self fulfilling when they measure parameters selected on the basis of certain presumptions. It is also evident that the scientific facts produced by such reductionist science could be more tenacious than 'irrational' ideologies. The general public is also socialized by survey findings on cognitive difference. Biological and psychological beliefs about women's scientific abilities also have an impact women's self perception leading to self-ejection from the field at various stages. Studies in the US show that articles carrying the names of male author are more likely to be read than those with women's names (Schiebinger 1999).

In France for instance, the biological thesis of inferiority of women's minds may have become rare, but biological explanations for women's' performance continue to be fielded for their relative absence in the hard sciences. Psychological traits such as shyness, lack of self confidence, referring to luck instead of taking credit for discoveries, linguistic abilities in modes of expression and styles of thinking are invoked to explain the same (de Cheveigne 2009). The pressures associated with motherhood are also discussed in this context. de Cheveigne (2009;117) observes that in the US, 'discrimination' is a frequent explanation for the paucity of women in scientific fields, while 'the French tend to focus on girls' disaffection with natural sciences at the higher secondary school level' . Similar trends have been noted in the Netherlands and Sweden.

Interestingly, feminists and others who seek to refute the bias against women also resort to biological, genetic and psychometric studies to prove their point and the discussion therefore revolves around women's cognitive ability and natural aptitude[13]. Women's lack of biological predisposition or aptitude for hard science is often a part of tacit understanding of male scientists that is reflected in sexist jokes among male scientists and a refusal to accept the need for gender equity even in the 21st century.

Gender discrimination stemming from theories about the cognitive inferiority of women is not the problem in India. Women scientists report how they were high performers in school and their abilities were not doubted (Subrahmanyan 1998; 90). The objection to women's professional attainment was the possibility that they would mix with men freely and defy familial roles. As long as they did not show much deviance from domesticity despite higher pursuits, there was no problem. Both girls and boys are expected to be loyal to the family. Krishnaraj puts it aptly: 'The American stark dichotomy of girls being "nurturing" and boys being competitive and outside -world looking does not operate to the same degree. Jaiswal's 1981 study of men and women engineers as well as Rahman and others on Indian scientists took note of the family-centeredness of men in India. The girls faced greater restriction on movement outside the home

[13] See for instance Castillo, Grazzi and Tacsir 2014

but they had negligible anxiety that a successful career in science would lead to loss of femininity. In fact, the Indian girls had high achievement motivation. The North American by contrast had greater anxiety because of the historical cultural dichotomisation of the nature of maleness and femaleness that has existed in western culture, whereas in Asian societies there is much more complementarily which leaves women to model themselves in new endeavours which in the west would be categorized as male and female (in Asia men could be typists and women doctors)' (Krishnaraj 1991; 111).

In her socio-historical account of women in medicine during the colonial period, Minocha (1996) talks about British women doctors facing gender discrimination in their country coming to the colonies for work. The objection to Indian women on the other hand, entering collegiate education in medicine was the fear of free intermixing of men and women and mixing of women of different castes. Cognitive abilities of women were not subject to any doubt. Rather it seemed that women's potential was appreciated leading to the fear that they may defy norms of familial and caste honour if they were permitted to study.

Mukhopadhyay (2009) argues that though statistical similarities in the gender gap in women in science and engineering subjects may be noted in India and America, theories of gender from the US are not valid for the Indian situation. She argues that different causes and cultural contexts could produce similar patterns and it is imperative to examine this difference carefully. She explains that bipolar characterisation of the biological and psychological traits of men and women colours much of the educational research in the US and folk explanations for the gender gap. They link biological traits to the cognitive abilities of women in mathematical sciences. The insistence on the hormonal system of the women which makes them more emotional is one such example. Whereas her statistical study among Indian women reveals that their explanations focussed on social contexts while assuming the scientific potential to be same in men and women. In short, the viewpoints in India bore no traces of biological or psychological essentialism based on cognitive abilities.

Women scientists studied by Subrahmanyan (1998) at Madras University did not attribute their career problems to bias about their abilities. There were problems such as – stalling the promotion of an outspoken women, inbreeding and preventing qualified people from other institutions entering the system and HOD's discretionary powers that necessitates a feudal relationship with ones superiors. But they pointed out that these problems were also experienced by men. In-breeding in universities deprives women of opportunities more because they often move places with their husband. In getting special opportunities like examiner status which require contacts with administrative staff, women were disadvantaged. Security issues in staying back in the laboratory, gaining access to funding agencies and socializing with VIPs in the field were key factors that reduced the upward mobility of women scientists. Exclusion from the scientific community and the inability to create networks with decision makers to get grants for research, not being able to travel much due to family obligations were the main issues reported by the women in the study. Krishnaraj's study revealed that at lower levels women did not report discrimination but about 20 percent of her sample of 400 women in science and technology sectors in Bombay who had reached high positions and aspired to do better, expressed that they faced discrimination. In Krishnaraj's study of Bombay institutions (1991), about 142 out of 400 women scientists and technologists said they had changed their job for better prospects.

The survey (2012) on women engineers in India and the US cited earlier also corroborates our point: that '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' (2012;13).

Almost all studies in different parts of the country (Krishnaraj 1991, Jaiswal 1993, Mukhopadyaya and Seymour 1994, Subrahmanyan 1998, Sur 2011) find that women scientists and technologists come from urban and well off socio-economic background. This is not necessarily the case with male scientists. Several women scientists reported that their fathers who encouraged them were professionals or in the services, though 50 percent of the mothers of women scientists were less educated. The social status of their family was critical for women who wished to reach higher levels in the science and technology professions. They always tended to marry up or marry someone more qualified and accomplished than themselves. The social status of the natal family and the family of marriage are both critical to women aspiring for higher positions, while for men, the status and support of the family of marriage, namely the wife, is more crucial. Male scientists did come from humble backgrounds unlike women.

But social background and familial backing which facilitates women's entry and rise in the profession does not take them too far; a very small proportion of women scientists in their late mid-career could achieve apex positions.

The Role of Family: Boon or Bane?

Women scientists across the world come from urban and highly educated or well placed social background. In the west, marriage and family clearly seem to be disadvantageous to women's scientific career. In the US and Europe, the proportion of unmarried women is greater in certain fields of science and technology, for instance, 38 percent white women chemists were single compared to 18 percent African- American women chemists (Sutherland 1985 c.f Subrahmanyan 1998). A larger proportion of women scientists remained childless in Europe: 37 percent of women scientists above 50 years of age were childless compared to 9 percent of men. Only 17 percent of women full professors of engineering had children whereas 82 percent of men did. While professional men were married to homemakers, nearly every married woman scientist was married to a professional. The lifelong support of wives who also assisted their husbands' work is a great strength to male scientists, though the wives labour towards the support of husband's career is invisible. Professional men with working wife are found to earn 25 percent less than others in the US, a phenomenon known as 'Daddy penalty'. Sutherland's study in Europe shows that the proportion of unmarried women is greater among the academics (ibid).

An overwhelming majority of women scientists in India are married and are married to men with comparable or higher qualifications within the academy; about with 50 percent of them have opted for 'self arranged marriage'. Women scientists in India like in other parts of the world, were hypergamous, marrying professionals or scientists of equal or higher accomplishment. Gupta and Sharma's study (2003) in 4 institutes - IIT (D), IIT Kharagpur, Roorkee and Jadavpur showed that 80 percent of women scientists were married of which 20.5 lived in joint families, 15.6 percent were single and 2.6 percent were divorced. 76 percent of the women took up their present position after marriage. As early as the late eighties Krishnaraj (1991) found that more than 63 percent of her sample of 1234 women professionals in science and technology fields in Bombay said that they received positive encouragement and support from -in laws and 25 percent said they were accepted. The extended family in India seems to contribute to child care facilities as institutional support from the government in these areas are near to absent. Further, Indian women employ cheap domestic help for household chores and baby- sitting, something too expensive in Europe and US. 85 percent women and 62 percent men among the 1544 members of the US Institute of physics said they do not attended conferences because of childcare responsibilities. For those beginning their career in US and Europe, the cost of childcare may often be higher than the amount earned. In India, the family has certain economic and social functions for the career of women scientists.

How do we understand the role of the family as an institution in the career of the woman scientist in India? Considering the fact that most of the women scientists who have attained higher positions are from upper castes or class, we have to see how important family as a social institution has been for these sections to reproduce their social position in a competitive world. As we have seen, women's participation in science and technology sectors is enabled by family support. The women cannot repudiate their allegiance to the family which helps them sustain them where they are. Hence they do not venture into anything that will violate their commitment to family and children. A majority of Indian women professionals have reported support from father in entering into higher education. It is argued that equality with men at workplace does not concern them because their class status is derived from their family. In India, single women were not as productive as married women because they do not socialize much and also had weaker social networks (Sur 2011)

A majority of studies report that women scientists suffer from dual burden of domestic and official work to varying degrees. But they also report that they enjoy support from the husband and his family. Motherhood is a key responsibility and studies note a slump in the performance of Indian women scientists when their children reach higher secondary school. Women evolve personalized solutions to childcare and nursing infants by maintaining docility and good relations with the departmental heads. The relations within family reproduced at workplace. Accomplished women scientists expressed contentment with family support and did not seem to think that they could do more in their career. Balancing career and family seems to be their ideal. Problems like drug abuse and alcoholism do not seem to be high among the children of scientists in India. In fact, their children are able to enter the global economy with high qualifications and good positions. This indicates that women scientists have been able to manage both the production and reproduction of cultural capital by investing in the family. The institution of family serves as the jumping board for women entering a science career; the constant support of relatives and spouse is critical for the women to achieve their desired ideal of balance between work and domestic responsibilities. This very commitment to the family, specifically, to the upbringing of children and ensuring their entry into the economic order is the reason for the inability of women to progress beyond a certain level in their career. Studies on women scientists cited above repeatedly mention how commitment to family makes it difficult for women scientist to work long hours and execute research programmes rigorously. At higher levels of scientific and technological research where unflinching attention to projects and laboratory work is essential, family becomes a deterrent. The future of their children becomes more important. This is true of men and women in India, though it is truer of women scientists. Studies on the self-perception of women corroborate this point.

Self-perception and Job Satisfaction of Women Scientists

With the exception of girls who entering engineering education from the lower class background, studies across the country show that there is no expectation of financial support for girls from the elite sections pursuing higher level science education due to protectionism. Girls may take up research in an area of their choice without the constraint of having to find gainful employment, something which would be important for their male siblings (Mukhopadyay 1994; 109, Subrahmanyan 1998). Most studies observe that a larger proportion of women than men say that they chose a science career out of interest. Jaiswal's study of 122 men and 158 women in 3 south Indian cities showed that women had secured better grades in graduation and post graduation than men. His study showed a larger number of women in senior positions in science and technology organizations in the public sector and universities than men. About 70 percent of his sample also noted that they sought the job out of self motivation and not for livelihood. Similarly more than 50 percent of the women professionals said that they were not accountable to anyone in spending their salary (Jaiswal 1993). 80.5 percent of successful and accomplished women scientists in Subrahmanyam's study of Madras University reported that success meant balance between work and home; male scientists did not think like this about themselves. The women scientists in her study seem to have attained an overall balance co-ordination between career and home, highly educated and well placed children, foreign trips and moderate networking and improved productivity after 50 years. In relation to their mothers, the women scientists have achieved considerable social mobility and have been able to transmit the benefits to their off spring.

It is not surprising that some researchers found that though job satisfaction is high among women scientists, *job commitment women is low and they are ready to quit anytime* depending on family circumstances (Kalarani 1975 c.f Subrahmanyan), ambition is low and their coping strategies involve conflict avoidance rather than being action-oriented.

Women scientists did not complain much about gender discrimination at work; they attributed career stagnation to general problems that affect the system such as poor infrastructure at work, noise and crowd, no equipment and laboratory facilities. Hierarchical discrimination by departmental head and seniors, jealousy and secrecy and lack of resources are problems, but the women opined that they that affect men and women. They need collaboration with scientists abroad and grants to procure the equipment for their research. Enterprising women do manage some of this. Cutting edge research may not be possible though individual successes and international publications are possible.

In Kurup and Maitrayee's study (2011) of 568 women and 161 men scientists, only 2–5 percent of women informants mentioned discrimination, marginalization, harassment and lack of flexible timings as problems, while most women mentioned family responsibilities as deterrents for a continuous career. Of the three slots on hours of work per week, namely below 40 hours, 40–60 hours and above 60 hours of work, a larger proportion of women scientists putting in 40-60 hours of work per week than men, though there were more men putting in more than 60 hours of work per week. Their data showed that the proportion of men in the below 40 hours was also greater indicating moderate and steady work habits of women scientists.

The critical question here is how does one understand the denial of gender discrimination in science by the women scientist? Does it mean that there is acquiescence on their part to dominant ideologies or that there is no discrimination at all? (Sur 2011) Subrahmanyan (1998) noted that none of her informants ever used the world 'feminism,' even though the younger lot challenged patriarchal ideologies and practices.

In her study of women scientists in C.V.Raman's laboratory, Abha Sur also found that her informant Prof. Anna Mani reported that she did not experience any discrimination at the organisational level. In later life, however, she admitted to personalized gender discrimination in public spaces. 'She seemed to implicitly to differentiate between social relations in laboratories, which mimicked gender relations in society at large, and bureaucratic structures of scientific and technical institutions, which touted their "gender- blind" rules and regulations' (Sur 2011, 181). In other words, the scientist distinguished between biases of certain individuals from the rules and regulation of the organisation thereby asserting equality as far as evaluative structures in science were concerned while identifying with Indian women who faced gender discrimination in general.

More importantly, Sur makes an important observation that Mani saw herself as a beneficiary of the institutional and social privileges accruing to her class in comparison to personalized gender discrimination. Further her nationalist sentiments and the absence of victim politics made Prof. Mani a stoic votary of no special consideration for women. She thought of institutions and norms as gender neutral and discrimination as acts of individual men. Sur hence argues that women scientists were not gender blind as much as they took gender equality for granted. State and bureaucracy were seen as neutral whereas society was the site of gender discrimination.

Bureaucratic requirements in science institutions may be fulfilled, but it is also necessary to examine the impact of intellectual engagement on selfhood of women scientists. Krishnaraj (1991) did make an attempt to probe into the extent to which science career influences their outlook to life. Among her informants, science was a passion for some women; others saw science as career. Some noted satisfaction from intellectual work, inculcation of scientific temper and practical solutions to daily problems as the rewards. Very few talked about philosophy and methodology of science and their curiosity seemed to be restricted to discipline. Her informants who were women scientists and engineers from Bombay said they rejected superstitions and did not follow all rituals. They all reported that they paid greater attention to the intellectual and emotional growth of their children. In fact some of them even said that this was the purpose of their knowledge of science. Motherhood was a central axis of her informant's preoccupation while this did not prevent them from pursuing a career in science and technology, it did come in conflict with their career growth at higher levels.

Lastly, another crucial question, namely, whether women scientist tried to independently overcome the impediments to the growth of scientific research in the country which are also faced by men, remains (Subrahmanyam 1998). The author observes that the scientific establishment in India is not affected so much by constraint of knowing the English language as in other Asian countries, but by hierarchy between universities and institutes and virtual lack of communication within scientists in the country. In other words, there was little or no sense of epistemic community among the scientists in India. Moreover, there was an arrogance and contempt for traditional sciences among the Indian scientists (Altbach 1989 c.f Subrahmanyam 1998). The question is whether the women scientists were any different or more creative in their work.

Subrahmanyan (1998) points out that most women scientists in her study reproduced the same attitude as their male counterparts. They were critical of science in this country and assigned poor value to peer's research. One biochemist in her study at Madras University was ostracized for working on botanical inputs from ayurveda. The women scientists in her study chose their research problems from foreign journals and consciously took up projects on what they referred to as 'modern' topics or internationally popular themes rather than those of significance in the Indian context. This was also the view of women scientists in the medical sciences. Questions about the originality and intellectual autonomy of women scientists are yet to be examined deeply because the field is saturated with quantitative measurement of women's participation in science.

Sur (2008) pointed out how the theories of biological differences, evolutionary theory coupled with eugenics and sophisticated psychological tests to measure intellectual quotient have time and again legitimised a social order rooted in sexism, racism and colonialism. The persistent efforts of women scientists within the gamut of science to expose, debunk these faulty experiments, intentional manoeuvring of data and gaps in methodology therein, have changed the situation to a great extent. The creative interventions by women scientists in the conceptualisation and design of experiments have to be viewed as critiques of the gender, race, class bias that permeates the very methodology of science.

We do not have much work in India on women's creative intellectual contributions in science and technology institutions as much as in the arts, music and dance. Whether lesser pressure to earn for the family allows them to pursue unconventional paths of research or do they submit to both the authority structures of the Indian family and of the science establishment in the west remains to be seen. The entry of women of depressed castes in science and technology sector and their manner of research also needs to be looked into.

The literature on women and science in India attributes the lower proportion of women in science and technology to the *patrifocal nature of the Indian social institutions* (Mukhopadhyay and Seymour 1994, Subrahmanyan 1998, Gupta and Sharma 2003), without explaining where and how patrifocality works. Rather there is a prior assumption that it is always a negative thing. This paper has shown how this presumption leads to the glossing over of interesting cues in their own data about the crucial role of the family in the career of the women scientists in India that insulates them from the vagaries of the labour market and allows them to reach tenured positions by middle-age.

Conclusion

The literature on women in science that this paper has surveyed relies heavily on percentages and figures, nevertheless, allow us to answer some of the questions raised in the beginning. Women's participation in the field of science and technology is poor in countries with highly advanced scientific research despite progressive social policies and individual rights, because the culture of science draws heavily on an entrenched biological and psychological essentialism about women's cognitive abilities, leading to a 'leaky pipeline' and self ejection by women. In the Indian situation there is no leaky pipeline. There are strong barriers to women's upward mobility in scientific and technological fields in India, but there is little or no essentialism of the kind mentioned above in the culture of science. The protectionism of the patrifocal family does permit women of upper castes and classes to pursue advanced professional education without the hassles of the competitive labour market. Women who have achieved a certain level in their professional scientific career will then have to make this possible for the next generation. The centrality of the family as an institution mediating social mobility in the rapidly transforming economy indicates how and why family-centered values continue to hold a mighty sway in this part of the world. Women's commitment to familial well being and the valuation of 'balance' between work and home could put a premium on docility as a key trait for success.

Studies of economy and of performance of the science and technology sector in India do not consider it worthwhile to look at the crucial role of the family here. Commitment to family and domestic responsibilities is a critical factor affecting performance of men and women in higher research, though women are more deeply implicated in the family affairs than men. Qualitative studies drawing upon narratives of men and women scientists may bring out deeper insights into these observations.

Organisational barriers to women's progress may very well be found in India, but the studies cited here do not indicate that bias about women's cognitive abilities in organisational procedures is a factor, or that women consider themselves as cognitively inferior to men in scientific abilities. Women students and scientists often report lack of preparation on their part or, lack of time due to domestic responsibilities for not moving up; not inability or lack of aptitude to do maths and hard science. The issue in the Indian situation would be the transmutation of the metaphor of family relations in professional relations leading to patronising and protective attitude to women colleagues on the part of men. In any case, we have to conclude that concepts like 'glass ceiling' or 'patrifocality' are inadequate to characterise the situation of women scientists in India, as are linear and liberal understanding of women's status in science.

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