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UNU-IAS Report

Revisiting Women's Participation in Science and Technology

Emerging Challenges and Agenda for Reform

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Cover photo "Scientist stirring liquid in flask"
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Foreword

UNU-IAS is one of the twelve research and training centres and programmes of the United Nations, and is devoted to research into the pressing global problems of human survival, development and welfare. This report is a reflection on the importance of the subject.

Socio-economic development has been one of the core issues of concern to the United Nations and its agencies. Under this broad theme, gender and technology are two leading subjects that drive and impact many international processes. Goal three of the Millennium Development Goals is exclusively on gender and states, "Promote gender equality and empower women". Science and technology have a tremendous potential in helping to achieve this goal.

The impact of science and technology on women is twofold. Firstly they offer new opportunities for empowering women through learning and employment, and secondly they may reduce the market demand for unskilled female labour. These two impacts are particularly pronounced in developing countries.

Women interact with knowledge-driven development processes. Their intellectual potential is an asset that cannot be ignored by economies, yet there are many complications in the process of utilizing this asset fully. Information technology is having an immense impact on socio-economic development: it is changing cultures, removing social and geographical barriers and offering new opportunities to those otherwise isolated. These changes place "gender issues" in a new perspective -- it is therefore essential to understand these changes, adapt to them and try to benefit from them.

This report is an attempt to understand the above challenges and to identify some of the most important policies that could support a greater involvement of women in science and technology.

A.H. Zakri
Director, UNU-IAS

Executive summary

The 21st century is witnessing the ever-increasing role of science and technology in all aspects of life. Science and technology offer the prospect of finding solutions for many global problems. The global challenges drawn up by world leaders at the Millennium Summit demand an unprecedented and extensive use of knowledge to enhance the welfare of all human beings. Despite constituting half of the population, women are an underutilized talent. Their contribution to the development of the knowledge base and the use of technology is essential if the Millennium challenges are to be met. The third of the Millennium Development Goals calls for gender equality and the empowering of women. Technology is a tool that helps to achieve this goal.

Women in general do not have a strong presence in science and technology. This is attributed to two broad issues: first, women's perception of their role and function in society, and second, society's expectation of their contribution. Women's involvement in science and technology encounters bias in regard to disciplines and academic or professional level of responsibility. Women are divided between two spheres: the management of the home and family, and the fulfilment of job responsibilities. Family commitments, either as the women's choice or as a result of cultural enforcement, have impaired women's capacity to meet their potential, and put them at a disadvantage in many science and technology-related jobs that are dynamic and competitive in nature.

This report reviews the limited literature available, and explores how women's role in advancing and using science and technology for society could be improved, and how science and technology impact women. In the education sector, although women constitute a large proportion of undergraduate students in many countries, the number decreases at the higher level and very few reach the top scientific positions. There is a continuous decline as we move up the academic ladder, and many highly-educated women are lost along the way. Gender difference also exists in the selection of academic fields in which to specialize: women are more inclined towards the arts and social sciences than the natural sciences and engineering. In industry, women are more involved in jobs demanding physical labour, and very few are in the most rewarding positions that demand technical skills and creative minds.

Changes are, however, taking place. Information technology not only empowers women through learning, it also crosses cultural and geographical barriers, bringing women to the forefront of society. The issues concerning women are very similar across different countries -- the differences are mainly in the magnitude of change rather than in the substance.

Despite steady but slow progress in increasing the involvement of women in science and technology, more effort is needed to bring gender issues into the mainstream. Exploiting the talents of women should no longer be looked at only from the perspective of gender equality: governments should regard women's involvement in science and technology as an essential component of economic development.

Tapping into women's intellectual potential requires changes both at the individual level and that of society. Guiding these changes is a critical responsibility of governments and civil society organizations. Governments need to provide an appropriate policy environment which helps women to balance family and professional responsibilities: policies that recognize and harness women's intellectual abilities, and that reward excellence. Policies are also needed to ensure that women's education gives them the tools they need to be competitive in the job market. Cultural policies are required to focus on values in support of women's participation in science and technology, and to grant equal rights to women engaged in technological fields.

An important factor in achieving these reforms will be a greater presence of women in decision-making bodies, be they scientific or political. The voice of women in governance is required to create the political will essential to bring about changes that will benefit all of society.

1 Introduction

The dawn of the 21st century has been marked by a transformation in which knowledge has become the central focus and driving force of human development, and pushes the boundaries at a dramatic speed and across a broad range of activities. This transformation is leading the industrial world towards a knowledge-based society at a rate far greater than that of the replacement of an agrarian with an industrial society in the late twentieth century.[1] Although the changes are primarily impacting industrialized countries, developing countries are also affected to a varying extent. Technological capabilities are now a crucial production factor that drives changes in a wider context. Knowledge is assuming a greater role in the economy -- consequently the demand for skilled labour has increased.

The transformation process into the information or knowledge-based society is the leading influence on innovation and development programmes and scenarios for the future. It will affect human development in manifold ways: the economy by more intense global competition and new forms of work and its organization; politics by new decision-making processes and the concepts of equality and diversity; society by an increasing degree of freedom of choice by the individual. All have direct and indirect effects on gender relations. The term "gender" refers to the socially-constructed attributes of the roles women and men play in society. It is changeable over time and has a wide variation between and within cultures. It encompasses economic, social, political and cultural attributes and opportunities associated with being women or men. Technology affects many of these attributes, and thus has an impact on gender relations.

A knowledge-based society is one in which science and technological knowledge affect all social levels – knowledge becomes a strategic resource for everyone. "Mental labour" is a central factor of production, alongside physical labour, capital, property and power. Products based on such mental labour are a common reality in daily life.[2] The knowledge-based society demands a redefinition of the role of women -- in the way that technology affects women at work and at home, the way that women affect the development and application of technology, and in what all of this implies for gender equality and social justice in the quest for sustainable human development.[3]

Knowledge in science and technology as commonly understood provide the intellectual capital or mental labour that can be exchanged for earning a living. Knowledge-based economies have developed an extensive application of knowledge in production sectors. Science and technology affect women and cut across all areas of life, particularly economics, education, training and the environment. Women form half of the population, half the school entrants, half the college graduates, and half the consumers of technology products, but they have little involvement in the forces that drive the changes which have such a great impact on their lives.

The absence of women in the "knowledge domain" of society will aggravate existing gender inequalities and their socio-economic consequences.

Gender equality has been the subject of many international efforts, starting as early as 1946 with the United Nations Commission on the Status of Women. The culmination of these efforts resulted in the adoption of the Convention on the Elimination of All Forms of Discrimination against Women in 1979. Article 14 of the Convention articulates the importance of technology in achieving its objectives. The Convention's focus is on fulfilling human rights and social justice for women. Access to science and technology by women has been emphasized at many international conferences, in particular in the Beijing Declaration released at the Fourth World Conference on Women in 1995.[i]

The deep and extensive roots of science and technology in all aspects of life have made this an overriding subject in the gender debate. Women's empowerment through science and technology has the potential to enable them to realize their potential and shape their life in accordance with their aspirations, and also to strengthen the advancement of science and wealth accumulation.[4] However, realizing this potential is challenged with many variables. Empowerment is the core element of human development, and human development is a process of enlarging people's choices. Therefore women's empowerment is a process that involves changes over a period of time, and widens the choices available to women in fully realizing their potential. This is a broad process that involves every segment of society, and highlights the daunting task ahead in fully realizing gender equality.

Arriving at gender equality, or as it is generally understood offering the same opportunities to women as are available to men, is an objective that strengthens human rights and social justice as laid out in international law, and is supportive of the globalization process by capturing the potential contribution of women to development . Science and technology, being the major drivers of development, provide a window of opportunity for women to influence the development process through participating in the advancement and application of knowledge. Greater involvement of women in science and technology is a vital interest for society at large – how that is achieved is not the problem of women alone, but one that requires the whole of society to engage in and address.[5]

[i] *Beijing Declaration was adopted at The United Nations Fourth World Conference on Women, held in Beijing, China in 1995. Available at: http://www.un.org/esa/gopher-data/conf/fwcw/off/a--20.en*

2 Participation of women in science and technology

Science and technology encompass a broad range of activities: how they relate to women depends on how they are defined. Science is often equated with knowledge that is concerned with the physical world and its phenomena, and that entails unbiased observations and systematic experimentation, whereas technology is the application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment.[6] From these broad perspectives, women have traditionally been important incubators of knowledge and the means by which it is transferred, mostly a contextual and uncodified knowledge rooted in experience.[7] What are regarded today as "science and technology" as they relate to women, are often seen within the context of human development, limiting the broad scope of science and technology to an empowerment tool. Women's participation in science and technology therefore refers to the extent that women have been able to utilize this tool in capturing the same opportunities available to men, ranging from research to high-skilled employment in firms.

The traditional gender divide in professions is being challenged by the pressures for new knowledge -- this has created a growing demand for hiring skilled labour in the research and production sectors. The global trend indicates an overall improvement in the level of education and skills of women. In many industrialized countries the ageing of the population, increased longevity and low birth rates which are not compensated by corresponding immigration rates have led to additional demand for the greater involvement of women in the labour market. New technologies are offering employment opportunities where intellectual and specialized skills matter more than physical labour. According to the Bureau of Labour Statistics, the number of jobs requiring science and technology skills in the US labour force is growing by almost five per cent per year, whereas the rest of the labour force is growing at just over one per cent.[8] However, the extent to which these increased opportunities are benefiting women is unclear. Data on the actual participation of women and the subsequent socio-economic impact on their development are scarce. Women's participation in science and technology through enhanced employment opportunities is mainly in those industries that are producing knowledge-intensive products.

The involvement of women in knowledge production is through their participation in academic activities. These entail both the education and subsequent employment of women. The education phase develops skills and empowers, whereas higher up the academic ladder, the person as a professional begins to contribute to science and technology development. The education phase is distinct in many ways from the later professional phase of academic life. At the education period, there is very little gender competition and women are free from motherhood responsibilities, whereas in the later professional academic life, family commitments make it harder for women to continue. This produces a continuum in which the number of women decreases up the academic ladder. This continuum has three characteristics: a high number of women at the level of basic degree and low number at the level of specialized degrees, gender differences in selection of academic fields, and a low number of women as professional academics.

2.1 Women in the education continuum

Education is the key to women's participation in science and technology. The overall global trend in education shows that women's literacy rate has improved, particularly in developing countries. The gap between female and male literacy is narrowing. The adult literacy rate among women in developing countries stands at 75.9 per cent, compared to the corresponding male adult literacy rate of 89 per cent; the figure for young women is higher, standing at 85 per cent compared to the equivalent male youth literacy rate of 95 per cent, indicating an improvement in access to education by girls.[9] But there are still many places, especially in the Least Developed Countries, where fewer girls than boys have access to primary education, and still fewer learn about science. The situation is the same for secondary and tertiary education.[4]

The number of women entering tertiary education has also improved in many countries, but this is closely related to the wealth of the society in which they live. All but seven of the 5 countries with a high Human Development Index (HDI)[ii] have more female enrolments compared to males – the exceptions are Japan, Switzerland, Germany, South Korea, Chile and Mexico. Hong Kong was also an exception. For the 86 countries ranking medium in their HDI, nearly half have more female enrolments than males. For the 36 countries with a low HDI, only two have higher female enrolment and the remaining have fewer women enrolling for tertiary education than men.[9]

Of the girls who do get tertiary education, very few study in the fields of science and technology. This deprives them of many of the job opportunities that are created by new technologies and that require high skills. A Malaysian case study reinforces this observation, showing that the education of women has greatly improved their entry into new technology jobs and into the urban economy.[10] Education is a key and crosscutting factor in empowering women and increasing their competitiveness with men for employment opportunities and for starting their own business. There is a clear relationship between education and starting entrepreneurial activities. For example, in high-income countries, 57 per cent of those who start an entrepreneurial activity have a post-secondary degree as compared to 38 per cent in a middle-income country, and 23 per cent in low-income countries.[11]

[ii] The Human Development Index measures a country's achievements in three aspects of humandevelopment: longevity, knowledge, and a decent standard of living. Longevity is measured by lifeexpectancy at birth; knowledge is measured by a combination of the adult literacy rate and the combinedgross primary, secondary, and tertiary enrolment ratio; and standard of living, as measured by GDP percapita / PPP US$ (UNDP Human Development Reports, available at<http://hdr.undp.org/statistics/faq.cfm#1>).

2.2 Gender differences in selection of academic fields

Women do have different preferences from men in choosing their academic field, and the pattern is similar in developing and most industrialized countries. Women are more likely to enrol in humanities, arts and education, with social sciences the next preference, while natural science and engineering are the least favoured fields.

Women in industrialized countries generally enjoy greater opportunities to enter universities, yet the tendency to pursue science and technology studies is low. In the European Union (EU) and Japan, about 70 per cent of students who major in the humanities, arts and education are female. While in the EU 60 per cent of social science students are women, Japan has only 30 per cent of female students in social science. In the scientific fields, female students favour medical science and health-related services (close to 75 per cent for the EU and 60 per cent for Japan). In contrast, female students have a very restricted presence in the natural sciences and especially in engineering.

The proportion of women in technical specializations within the broad field of technology varies widely. For example in the federal state of Baden-Württemberg, Germany, in 2000 only 7.5 per cent of students in the faculty of electrical engineering were female, but 19.9 per cent of the faculty of civil engineering and more than 50 per cent of bio-engineering students were women.[12] The number of female students pursuing natural sciences in the EU is higher than that of Japan, standing at 40 per cent and 25 per cent respectively. In the field of engineering, the equivalent figures are about 20 per cent and 10 per cent. Changing these preferences requires a holistic approach that engages society at large and targets cultural change and individual perceptions. Measures in the European Union to increase female participation in science and technology studies have so far turned out to have no significant effect.[13]

Despite similar preferences between women in Japan and in the EU in choosing science disciplines, women in European countries generally opt more for male-dominated disciplines than Japanese women, indicating the cultural influence on their choice of academic field. Within the EU there are varying degrees of discipline preferences between the member states. For example, women in Portugal and Italy compared to other EU countries are known to have a stronger preference for science, followed by mathematics, computing, engineering, manufacturing, and construction-related disciplines. In Germany, women are known to have less interest than men in natural science and engineering than in other EU countries.[13]

Although women do receive almost 40 per cent of all the PhDs in the EU countries, their distribution in different disciplines varies. Life sciences have the highest proportion of female PhD graduates (50 per cent), followed by mathematics (30 per cent), physical sciences (27 per cent), engineering (20 per cent) and computing (19 per cent).[14] It appears that women are less inclined to continue their specialized education in technology-related fields such as engineering and computing . Moreover, many who leave university after their first degree tend to get a less competitive and relatively lower-paid job in technology-related fields. In Denmark for example, 70.8 per cent of the technician workforce are female, whereas only 16.8 per cent of all academic researchers in technical fields are female. In Germany, women account for 49.9 per cent of all technicians, but only 12 per cent of academics in the relevant fields.[15] In Sweden, the pattern of selection of disciplines has not changed substantially in recent decades: women still appear to be steering clear of technology fields. The percentage of Swedish women in technology disciplines increased from 10 per cent in 1970 to 25 per cent in 1998, while the proportion of women in teaching disciplines has been constant at around 80 per cent over the past three decades.[16]

The reason for not choosing technology-related academic disciplines is not that women dislike them -- it is rather a complicated choice that has other reasons, some of which might be cultural, related to the nature of the technology sector itself, or to the job market these graduates are hoping to enter.

In many developing countries, the number of women doing specialized degrees is on the rise. However, a shortage of data makes any quantitative estimate difficult. In general, many of the issues raised above are also relevant to developing countries, but at a different magnitude owing to different level of socio-economic development and cultural differences.

2.3 Women as professional researchers

The presence of women researchers in scientific fields is a reflection of the choice they made in selecting an academic discipline at the time of their education.. Woman faculty members in EU universities are mostly in the fields of humanities, social science and medical science. In most EU countries, the percentage of women faculty members in natural science is around 20-35 per cent, and in engineering and technologies around 10-20 per cent The exception is Portugal, where women account for almost half of the natural science faculty and about 29 per cent of the engineering faculty.[13]

When we look at researchers in industry, women are also under-represented, despite an increase in the number graduating in science and technology fields. The proportion is only around 15 per cent in the EU, and 19 per cent in the US.[17] In Japan the figure is even lower, with women making up just 6 per cent of the workforce of industrial researchers. Again, within the EU some countries, such as Ireland, Greece, Portugal, France, do relatively better, with a female representation of 20 per cent or higher; others, such as Austria and Germany have less than 10 per cent of women researchers in industry.[17]

3 From education to career development

Education and employment are directly linked: effective and useful education leads to better employment opportunities, and better employment opportunities would serve as an attraction for new entrants into the education system. If a career in science and technology does not yield an employment advantage, education in these fields will seem unattractive.

Women have gained a fairly high level in education in quite a few countries: in some they are better educated compared to men, although the share varies widely by discipline. The question is, to what extent women have been able to transform the empowerment provided by education into employment opportunities. The environment of employment differs from that of education: there are different issues of concern when a woman enters into a professional position. Moving up the hierarchy is a particular challenge for women, as they have to compete with men. It is quite difficult to assess career opportunities in general, as career paths are rarely organized and documented, shortage of data makes any such assessment difficult. With this constraint, one of the few feasible comparisons seems to be that of career paths at universities.

3.1 Career path at universities

It is amply documented that "women are lost from the academic pipeline at a greater rate than their male counterparts".[14] A study of six EU states (Belgium, France, Germany, Netherlands, Spain and United Kingdom) shows that an equal number of female and male students enrol at universities, but the number of women decreases at the upper hierarchy of the university (starting from Ph.D. students, to Assistant Professor, to Associate Professor, to full Professor). This trend demonstrates that the so-called "leaky pipeline" tends to lose much more women than men on their way to higher academic status and position in the university hierarchy.[18]

It is argued that this trend is in contradiction with the continuously-increasing rate of women's participation in academic programs in the last three decades. A possible explanation is active discrimination.[19] In the case of Sweden, despite many incentives and a number of positive actions by the government, the relative number of men and women at Swedish universities by position show no change.[16]

Another indicator for the leaky pipeline in the academic hierarchy is membership of decision-making scientific boards. EU studies of the percentage of women members on scientific boards in the academies and universities point to this imbalance, and further indicate remarkable differences between the European member states.[13] The percentage of women in scientific boards of academies and universities in Luxembourg is 6.6 percent whereas in Portugal it is 66.7 percent. The reason for high percentage of women in scientific boards of academies and universities might be due to the fact that not only are more than 60 per cent of the students female, but women constitute two-thirds of all scientific board members. Among many factors, this might be explained by lower salaries at Portuguese universities compared with other European countries, making competition for membership of scientific boards less intense and hence easier for women to compete.

The pattern of women's participation in science and technology has changed from exclusion to segregation in three major forms. The expression "vertical segregation" refers to high concentration of women at certain levels of the professional hierarchy, and is used to describe their under or over-representation in that hierarchy. For example, women may constitute about half the undergraduates in some disciplines, but they represent a small fraction at the professor level.

Another expression is "horizontal segregation", which refers to the concentration of women in certain areas of science, such as biological and medical sciences. The third form is "contractual segregation" where men are more likely to have permanent tenure and women are more likely to be on short-term and part-time contracts.[14] Short-term scientists may become lost to the profession due to their inability to get a secured position. In addition, their work is affected by stress associated with uncertainty about their future. In some of the EU member states, the number of such short-term contracts is on the rise[21] and it is likely that many women choose short-term contracts due to easier entry requirements.

There is little information available on the situation of women in science and technology in the private sector. A survey of women in decision-making positions in the European telecommunications industry[22] shows that even in this young and modern industrial sector, the share of women in top management positions is 9.3 per cent (36 out of 388 top managers are female) and 9.1 per cent for positions in supervisory bodies and boards of directors (49 out of 538 board members are female). There is, however, a tendency among private firms to increase the proportion of women in managerial positions. Reasons such as enlarging the company's recruitment base and increasing diversity to enhance creativity are amongst the most important objectives of this policy.[23]

4 Why women fail to develop fully a science and technology career

The path to career development starts at the time a person receives university education. Education is a key factor in deciding the future career path of students, and educational institutions are also important in their success or otherwise in training individuals to make a living out of what they have learned. Societal and cultural factors are the key to defining which subject a woman might choose for her education. The existence of perceptions such as men's vs. women's academic disciplines skews the choice of women in early education.

Whether in academic professions or in industry, the number of women reduces further up the hierarchicy. For example in the US women constitute 19 per cent of industrial researchers,[17] 15 per cent of corporate staff in the Fortune 500 companies, 5.2 per cent of the 5 most highly paid staff in companies, and only 13.6 per cent of board seats.[24] A similar situation prevails in other employment sectors. For example, in academic organizations, women form the majority in many low-paid laboratory-based jobs. In addition, female employment is often associated with the service sector. This gender profile has changed employment opportunities in favour of women in such positions.

In order to promote women's participation in science and technology, it is essential to understand the pattern of employment and the reasons behind it. Most statistical data in this regard are, however, from developed countries and the shortage of data from developing countries is a constraint in understanding this pattern and coming up with measures to correct it.

Arriving at a higher rate of women's presence in science and technology fields requires a thorough understanding of the barriers they face at the time skilled women enter the job market Among the factors that have restrained women's further involvement in science and technology, the following three could be the most important : (i) gender pay gap, (ii) culture and gender inequity , and(iii) lack of political will.

4.1 Gender pay gap

In most OECD [iii] countries, women in scientific and technological professions receive lower salaries than men. Unfortunately, in recent years, the gender pay gap appears to be widening instead of narrowing.[26] This is better portrayed in the private sector where gender equality might be less regulated, whereas the public sector in many OECD countries has tougher regulations that promote gender equality in income.

The gender pay gap is wider for workers who completed upper-secondary education compared to those with a first-stage or lower-secondary education, and is widest for workers who received a higher education.[14] Women in Europe with higher education are likely to face more discrimination in terms of earnings: on average a European woman with a higher education qualification earns only 68 per cent of her male colleagues' income.

In the US, the median annual salary for women scientists and engineers was about 22 per cent less than the median salary for men in 2001.[27] Further, between 1993 and 1999, salaries for women scientists and engineers increased by 25 per cent compared with an increase of 28 per cent for men. According to the National Science Board, "Salary differentials varied by broad fields. In computer science and mathematics occupations in 1999, women's salaries were approximately 12 percent less than men's salaries, whereas there was a 23 percent salary difference in life science occupations, women also reported the highest and lowest median salaries; their highest median salary ($58 000) was in computer science and mathematics occupations and their lowest was in life science occupations ($39 000)". [28]

In the US, analysis of salary differences for female and male scientists and engineers in the Science and Engineering Indicators 2002[30] indicated the gender pay gap is highest for those with bachelor's degrees -- women earn 35 percent less -- and for people with PhD's, the difference amounts to 26 per cent. One of the reasons for gender pay gap is the higher share of women in lower paid fields such as social sciences and education related jobs.[30] This gap is increasing in some countries, for example in Canada, the salary gap between male and female engineers was about 11 per cent in 1999, an increase of 2.4 per cent compared to 1997.[26]

In Australia, women in science and technology occupations earned 63 per cent of the average annual income of their male colleagues. Part of the wage gap here can be explained by factors such as fewer years of work experience and the field in which a degree was obtained.[30] However, gender pay gap may be attributed to a number of various factors, according to the National Science Foundation "some or all of the unexplained gender salary gaps may be attributable to 'unequal pay for equal work'. Indeed, the size of the unexplained gap may even be underestimated".[31] However, the gender pay gap for female engineers was significantly lower than the gap in other sectors.[32]

4.2 Culture and gender inequity

The knowledge economy is driven by innovation, which in turn is influenced by economic incentives, and objectives such as improving the competitiveness of firms. However, denying opportunities to women scientists and innovators to fully participate in the innovation process and the knowledge economy, would be an opportunity loss for the nations. A greater integration of women's' scientists in knowledge economy requires a conducive culture that recognize and value women's intellectual workforce. There

[iii] *Organization for Economic Cooperation and Development*

are serious challenges in developing such a culture; cultures that insist on a strict hierarchical separation of women thinkers from the producers are unlikely to be conducive to innovation. Therefore, although economics and politics are the recognized forces in encouraging innovation, culture should also be recognized as an element that offers a wider participation opportunity for women to join in the process.

The cultural ceiling in some cultures effectively bars women from contributing to the creation of new technologies, the thought that technology is not for women is strongly embedded in the minds of many. Among the many factors, paying attention to some basic issues such as education and mass illiteracy among women is important in influencing such cultures.

Despite the widely accepted wisdom on the importance of women's participation in innovation and in knowledge economy, the matter is sometime overshadowed by other serious gender related issues that demand full attention of policy makers. For example, violence against women persists in some countries, in forms such as "dowry deaths", "honour killings", "acid throwing" and the chopping of limbs. This creates a difficult choice as to whether it is best to concentrate efforts on changing the cultural ethos in these countries, or to have programs that by-pass these values and promote women's participation in science and technology.

New technologies, particularly information technology in manufacturing, services and communications, have great promise in terms of dissolving the old basis of discrimination, such as heavy and light work, etc. The potential of these technologies for decentralized and more humane development, and enabling participatory political structures, have yet to be realized. There is no doubt that cultural values are important in promoting innovation, but it can be misleading for social analysts to regard cultural values as the sole foundation for an innovative society -- it can be tragic for decision-makers to do so.

4.3 Lack of political will

Political will from governments is essential for encouraging women's participation in science and technology. It can be assessed by use of the Gender Empowerment Measure (GEM), an important indicator that estimates women's empowerment through the number of seats occupied by women in the parliament or the number of female legislators, senior officials, professionals and technical workers; and the estimated ratio of female to male incomes. Political will could be demonstrated if governments improved their GEM.

Some countries with a high Human Development Index also have a high GEM, whereas for some others with a similar level of development, the GEM remains low. Political will in less developed countries has demonstrated its indispensable power in promoting women's role in society. Most of Eastern Europe, Central Asia and Mongolia have a higher participation rate of women in science and technology than West European countries because of the relative emphasis of the political regime on women's participation. Similarly, China is far better in terms of the participation of women in science and technology in comparison to neighbouring countries that share a similar cultural background.

To make the decision-making process more sensitive to the problems faced by women, the number of women on decision-making and policy advisory bodies has to be increased. The implications of the absence of women at these top- level positions in the science and technology sphere are significant, and leads to the marginalization of women in the allocation of opportunities such as research funding and employment. The absence of women in top political and managerial positions in educational and research institutions eliminates the opportunity of hearing the voices of women in key decisions on the current and future orientation of science and technology.

5 The impact of technology advancement on women's participation in science and technology and their employment

With the globalization of the skilled labour market and the shift from agriculture into manufacturing, commerce and services, technological developments have had a great impact on employment opportunities for women. This is not to imply that the direction of technological change has reversed so that it now benefits women where once it benefited men:[33] technological changes are rather an agent for social changes that redefine gender relations, family and sexuality.[34] Global employment trends indicate that there are more women in the labour force now than before, yet women have a higher unemployment rate than men. In 2003, more than 40 per cent of all people at work globally were women but the quality of employment by women is generally lower than men. Sixty per cent of the so called "working poor" – those earning less than the poverty baseline of a dollar a day -- are women.[35]

New technologies can improve women's competitiveness in selected areas where intellectual competence supersedes physical strength. However, whether women are able to take advantage of these opportunities depends primarily on socio-economic factors.

In Asia, for instance, there are three distinct patterns that describe women's participation in the labour force: the "double-peaked" labour supply curve where women participate prior to marriage and child-bearing and then return to the labour force when the children are older; the "single-peaked" pattern of early participation without a later return to the labour force; and the "plateau" where women do not interrupt their labour force participation for child-bearing.[36] Unskilled women enter and leave the labour force relatively more easily and through their own choice: this makes labour-intensive export industries particularly attractive to the female labour force. In Bangladesh, for example, women now make up fully 90 per cent of the more than 500,000 workers in the export-oriented garments industry. However, in the capital and in technology-intensive industries, men are employed in much higher proportions than women.[37]

The impact of new technologies on women can be either positive or negative. It depends on the context within which technology is being developed. Design of specific technology for women may be difficult, but an alternative strategy might be design technologies for activities that involve mostly women and improve their productivity. Having a process in which women could interact with technology developers is a useful way to reflect their requirements in the product under development.[38]

5.1 The impact of new technologies and new forms of organization on labour

New technologies provide the opportunity for women to acquire new skills that enable them to undertake tasks requiring multiple skills, logic, inventiveness and creativity that in turn increase their motivation to learn more.[39] This may offer more employment opportunities for women in areas that were not available or appropriate for them before.

One effect of mechanization and computerization of manufacturing is that it reduces the need for physical labour and increases the need for skilled labour. This opens up new possibilities for women to get employment in manufacturing fields after undergoing technical training. In the metallurgy industry in China, for example, women used to comprise only one per cent of the total work force, but with the introduction of new technologies, the 'heaviness' of work has reduced significantly. The proportion of women employed in the Beijing Iron and Steel Company, and in the Benxi Iron and Steel Company in Liaoning Province has gone up to 28 per cent in each case.[40] Further, with the abolition of the distinction between 'heavy' and 'light' work, it is easier to argue for equal wages for women.

Technology advancement can also lead to greater job security. The high cost of training workers in the skills necessary to operate expensive equipment makes employers reluctant to recruit new staff – they prefer to keep the skilled workers they have.

More recently, advances in information technologies have led to changes in the organization of work. The new environment is characterized by group working, Quality Control Circles (QCCs), and multi-tasking rather than assembly-line style single tasks. This new organization of work is more challenging and more beneficial to workers as they can learn and possess multiple skills.

Alongside this multi-tasking and the QCCs, however, men still have a monopoly over some areas of work. Men set the machines, while women operate them. In the expanding and technically-advancing Chinese computer industry, men dominate as workshop directors and supervisors. According to Zhou and Guo "This gender segregation is even more evident in the foreign subsidiaries with technologies which allow for international fragmentation of labour processes".[41]

While new technologies offer opportunities, they also challenge many unskilled women already employed in labour-intensive industries. As businesses replace old technologies with new ones, many of their existing low-skilled female workers are purged. For example, with the introduction of computers into banks in India, older women were not retrained: instead, preference was given to employing young workers who had some computer knowledge,[42] this women's employment opportunities if they are denied of equal opportunity to access education and empower themselves to new skill requirements. Similarly in Indian iron ore mines when manual loading gave way to mechanical loading, nearly all women were forced to retire, while men alone were retrained for new

jobs.[43] With the introduction of new technologies in Vietnam, according to Nguyen "many middle-aged women had to move to unskilled low paid job or to go to an early retirement without a clear future".[44]

5.2 Access to new technologies by women in developing countries

Even though human society as a whole is progressing quickly in the development of technology, there is a huge divide between the North and the South in terms of producers and users of the technologies. Developing countries are usually at the position of the lowest valued-added part of production process, and lagging behind in the use of new technologies The cheapness of female labour in the South often makes industries reluctant to switch to new technologies. Only when the new technology drives the price below the operating costs incurred with the old technology, would there be necessity to replace it.[45] In the garments industry, for instance, if the computerized systems become cheaper than the labour-intensive methods followed by some Asian economies, it will be difficult for the industry to confront international competition.

Many industries have experienced the disintegration of the global value chain of their production process, i.e. the segmentation of their manufacturing process into a number of distinct parts located in different parts of the world. This means that some countries might be left with only the labour-intensive and least income-generating parts of the process; design may be done in Paris, Rome or New York, the equipment may come from Japan or South Korea, the fabric from a few specialized suppliers and the cutting and stitching may be done in Bangladesh. Some new forms of segmentation have emerged with computerization. Singapore and to an extent Hong Kong have recognized themselves as organizers of production and supplies, rather than direct manufacturers. In the automobile industry, Japanese manufacturers have spread out different segments of production to different countries in Southeast Asia, while design remains concentrated in Japan itself. At a global level, some parts of data processing are now carried out in India and Singapore, using time differences to feed into the North American and European system. Computer software engineers located in parts of India now work as employees of American software manufacturers, giving rise to a new category of 'non resident alien workers'.

Cheap female labour in less developed countries may fall victim to this segmentation. Responding to new patterns of technological practices and adding greater value from women's labour require innovative solutions by governments.

5.3 Information and communication technology

Information and communication technology (ICT) is one of the most promising developments of recent times that has immense potential in addressing many gaps in human socio-economic development. Harnessing this potential, however, is a challenge that requires thoughtful planning. ICT can address some of the shortcomings in women's development. The declaration made at the World Summit on the Information Society[46] describes ICT as a tool in gender mainstreaming and equality. ICT can contribute to the political empowerment of women, improve their participation in the economy, and provide a better quality of life for women and their families. It is a gender-insensitive technology in the sense that both women and men can be benefit from it and can contribute to its content.

ICT is a delivery mechanism and a communication tool. It can help women to provide advocacy services to each other, to organize and develop a voice, to create public awareness of women's issues, to end women's isolation be it cultural or geographical, to access information and services. It can help them in setting up new businesses and engaging in e-commerce and e-business, to generate income and strengthen existing businesses, create new employment opportunities, improve access to formal and non-formal education, health services and other services that were formerly available only on site.[47] Advantages offered by ICT such as flexible time, working from home creates more flexible working conditions for women. Information technology does, therefore, constitute the basis for the redefinition of traditional gender norms, and offers a platform where women's interests, opinions and rights are taken into account.

The broad impact of ICT on women has two perspectives: it serves as a tool in gender mainstreaming, but it also allows women to take a more active part in technology development, including the ICT itself. The way technologies develop is now changing: production of ideas alone is no longer sufficient for accomplishing innovation. The workforce of the future has to be multi-skilled, and must involve collaboration between workers at different levels of skills and with different perspectives. Women, through the connectivity provided by ICT, can take a proactive role in technology development: being half the population, they can influence the direction of technology development by bringing their ideas and their consumer perspectives to bear in the shaping the direction of technology development.[48]

Women in some of developing countries are taking advantages of ICT and entering the new workforce it creates. In India, for example, there is a high intensity of women involved in ICT: it is estimated that women constitute 21 per cent of the total ICT workforce, which is higher than their participation rate in the national economy as a whole, now at 13 per cent.[49]

Women's entry in the ICT industry has had some socio-economic impact. Studies of village pay phones in rural Bangladesh[50] and computer-aided technologies and teleworking in Malaysia and India[51 52 53 54] have shown that household income has increased, and women have more

mobility and more say in domestic matters. But it is also pointed that women's work has multiplied as gender-based division of labour at home has been maintained.

Due to the limited data from developing countries, the full picture of the extent to which women make use of the potential of ICT is not clear. Concurrent and competing priorities in developing countries make progress in fully benefiting from ICT slow and difficult. Poor infrastructure, the high cost of getting online, the low number of female entrants into ICT-related education and fewer female entrepreneurs in ICT-related businesses, make the realization of the promise of ICT for women in developing countries a distant prospect.

5.4 Agricultural technologies and their impact on women

Agriculture by its nature has been a labour-intensive practice: in economies with a low per capita income, women attain a high share of employment in the agricultural sector. In 1997, more than 43 per cent of all agricultural workers in developing countries were women, and in Sub-Saharan Africa, the figure was more than 47 per cent. Of all women employed in the same year in the developing world, 63 percent worked in agriculture sector, and in Sub-Saharan Africa the figure was 75 per cent.[55] In general, the net effect of technological advances in the agriculture sector is an increase in productivity, which is often associated with a decrease in the labour force. Many women employed in agriculture have gradually moved to other sectors. Job creation in other sectors coupled with mechanization of agricultural practices has lowered the demand for female farm labour.

Yet in poor countries, agriculture is still feminized. In 1997, close to 70 per cent of rural women of working age in low-income countries with a deficit in food were engaged in agricultural work.[56] The subsistence nature of the agriculture practiced by households in the least developed countries gives it a low level of productivity, and modern agricultural technology has yet to fully be utilized by subsistence farmers. Poverty reduction, agricultural development and women's development are strongly inter-related. Much of the available agricultural technology is best suited for bigger farms and commercial type of agriculture. Mechanization in commercial agriculture in some instances has damaged the livelihoods of women, for example with the displacement of female labourers involved in transplanting rice in Taiwan and Thailand, and in rice husking in Bangladesh.[57] Alternative employment is often unavailable. The development and application of agricultural technologies suitable for subsistence practices have a great potential to help poverty alleviation through the participation of women farmers. By targeting women who are also poor, these technologies could play a significant role in achieving the Millennium Development Goals.

Women farmers in the least developed countries are often the source of indigenous knowledge, and complementing this with modern knowledge is essential if up to date technology is to find its way into the subsistence farms. By engaging women farmers in the tailoring of technology, giving them the chance to contribute their knowledge and exposing them to knowledge from outside their traditional environment, they can be given the chance to develop their creativity further, and come up with innovations that could help their livelihoods. Additionally, agricultural technologies have a great potential in creating off farm-employment opportunities for women. Small-scale processing plants provide added value to raw agricultural products, and they also create a demand for skilled labour, including women.

Agricultural technologies developed in the 1960s led to the so-called "Green Revolution", through which world cereal production was doubled in a period of around 45 years. Technology was freely provided to farmers, saving millions from hunger. The agricultural technologies of today are far more complicated than those of the 1960s, and agriculture is heavily dependent on innovation originating in other sectors, much of which is protected commercially or intellectually. The technology needs of women farmers to a large extent have to be met by continuous innovation, as technology becomes gradually more of a trade commodity, moving into the "private domain", which makes it difficult for poor women farmers to access. Public institutions at both the national and international levels that serve developing countries should realize they are the main source of agricultural technology to women in these countries.

5.5 Reproductive and health technologies

Women usually live longer than men, yet women in most communities seem to be less healthy than men. In some societies, despite the natural biological advantages of women, they have a shorter life expectancy due to their social disadvantages.[58] While the health care needs of women and men are to a large extent similar, women do have some particular needs such as the treatment of reproductive disorders.

It is true that there are many women working in the field of medical sciences as researchers and practitioners, but the direction of technology development and access to medical technologies by women do not fully reflect women's health care needs.

Unwanted pregnancy and disorders related to sexual behaviour compromise the well-being of women, yet it is men who usually have the initiative. Health care technology offers the possibility to women to regain control over unwanted pregnancy, and to protect themselves against sexually transmitted diseases. The spread of contraceptive technologies makes it possible for women to acquire what was always the preserve of

men - the separation of sexual activity from reproduction. However, cultural institutions in some societies shape the availability of reproductive technologies to women. The production of contraceptive technologies (the pill, IUD, injectable contraceptives, female sterilization) has been shaped by "sexual relations in combination with population policies and market forces".[59] Even the only male contraceptive technology developed (the condom) is now being promoted more as an anti-AIDS device, rather than as a method of contraception. The patriarchal nature of many states in developing countries plays a role in determining the type of technology promoted, if not developed.

New technologies have made it possible to extend gender discrimination even to the period before birth. Cheaply-available technologies for sex characterization before birth are being used in some countries to such an extent that the sex-balance ratio is disturbed. Most societies in Asia show a strong preference for a male child. In the pursuit of this preference, modern technology has been harnessed to the old systems of female infanticide and systematic neglect. Amniocentesis, intended to detect the prevalence of serious deformities in the fetus, is often used in Asia to detect another kind of socio-cultural deformity - female fetuses - and leads to their subsequent abortion. While the biological norm is that about 95 girls are born per 100 boys, in China, India, South Korea and Pakistan the figures are not only lower but also fell during the 1980s, with the mushrooming of amniocentesis centres. This is indigenization of global technology with a vengeance. As Soon-Young Yoon points out, "Indeed, modernization of health technology often replicates rather than challenges gender inequality".[32] As much of technology development and use is profit-driven, women appear to be a dispensable human resource in the process.

Conclusion

The knowledge economy has created a global understanding that does not recognize the divisions between human beings. Dividing lines, be it physical or virtual, are crossed over by the desire to create new knowledge and / or the application of knowledge. The gender divide is also challenged in the process by forces that drive knowledge-creation and application. It is no longer a choice for women whether or not to participate in science and technology: women's involvement is rather through a gradual and spontaneous transformation, closely tied to the knowledge push in the human development process. The development of women and the progress of science and technology are therefore related to one another. The transition to a knowledge-based economy would seem to be unsuccessful if half of the human resources are not engaged in the process of innovation.

It is necessary to recognize that the participation of women in science and technology is no longer simply an issue of gender equity: it is also an issue that should be considered in national economic development. Women are both consumers and producers, they can make a difference if they are involved and considered in economic development plans. With science and technology at the heart of economic development, women's participation in science and technology is therefore an essential part of economic development strategies.

In order to arrive at a greater involvement of women in economic development through their participation in science and technology, systematic and coherent policies are required such that gender issues are brought into the mainstream at all levels, including education, employment and governance. New technologies could assist in this endeavour if promoted. Information technology is empowering women by making education accessible, and raising women's skills.

The skilled labour market, be it in research or in the production sector, enables women to engage in activities which are largely intellectual, thus removing their inherent disadvantages in competing with men for jobs demanding mobility and physical labour. The presence of women would bring additional skilled human resources to countries at the forefront of knowledge development, which currently often rely on foreign migrant scientists. In less developed countries, women could contribute their traditional knowledge to help modern technologies to adapt to local conditions.

There are, however, barriers preventing the full engagement of women in science and technology: the lack of interest among women to pursue engineering and technology-related disciplines at universities indicates cultural influences that often regard these fields as the preserve of men. Even those women who pursue higher qualifications in engineering and technology face discrimination: in many places where women are equally competent, the man is given precedence in employment opportunities as he is regarded as the bread-winner. Such discrimination may range from unfairness at the point of hiring, salary gaps and bias in promotion opportunities. The role of educational institutions is indispensable in promoting cultural change. Universities in particular, as the think thanks of society, are best placed to take the lead in achieving social transformation through education, and making science and technology attractive to women. Women need to discover the fascination of science and technology.

In the poorest parts of the world, women do much of the family work which is often unremunerated. There is a need to acknowledge the value of women's contribution to family welfare and child- raising: this is often taken for granted. In many instances, family responsibilities erode opportunities that a woman might have in developing her capacity for engaging in paid work, by acquiring scientific or technological skills which would enable her to compete with men. Society needs to compensate women for their contribution to family welfare, and for the resultant loss of opportunity.

Government's role is crucial in bringing about these changes, through providing an adequate social infrastructure and policy environment which facilitate women's entry into the fields of science and technology. This could include measures to support the professional, personal and family needs of women through their education, career development and their employment. The exact nature of policies and measures to achieve this aim will differ, depending on the cultural environment and the level of economic development. An example of the type of policies which could be adopted include a childcare subsidy for working mothers, to acknowledge the contribution of women to society, and accommodate their needs as wives and mothers. Another policy might be to compensate employers with tax breaks for hiring women. Leaving all the problems to women or their employers will only strengthen the already imbalanced gender picture.

Political will from governments is a crucial element in promoting women's participation in science and technology. Civil society organizations are particularly important in helping the development of political will, and of cultural institutions that support women's participation in science and technology. Political will can be reflected in legislation that protects women's rights in every sphere of socio-economic life including science and technology, in programs that encourage women to pursue a scientific career, in academia as well as industry, and in reforms of social institutions that lead to society's appreciation of women scientists.

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