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TECHNOLOGY, COMMERCIALIZATION AND GENDER

A Global Perspective

Technology, Commercialization and Gender

Pooran Wynarczyk · Marina Ranga
Editors

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Foreword

The last two decades have brought rapid change in both the numbers of women in science, technology, engineering, and mathematics (STEM) and in technology itself. In the United States, in many of the social sciences and the life sciences, women have reached parity in the percentages of degrees received (NSF 2015). In other areas, such as the geosciences as well as mathematics and physical sciences, the percentages of women continue to increase, although they have not approached parity. In contrast, in engineering and computer sciences, the percentages of women have dropped during the past decade at the bachelor's level and also at the master's level in computer science. Despite the increases in numbers and percentages of women in most STEM disciplines, gender disparities remain between women scientists and their male colleagues.

The *Nature* article "Global gender disparities in science" (Lariviere et al. 2013) documented that fewer than 6% of countries represented in the Web of Science achieve gender parity in terms of papers published. The study showed that women have fewer authorships (30%) than men (70%), have almost half as many first authorships as men, have fewer international collaborations than men, and that women's papers receive fewer citations than those of their male colleagues. Although this *Nature* article presented new data, analyzing 5.4 million peer-reviewed globally published articles written by 27.3 million people between 2008 and 2012, the finding of the publication gap was not news. The "productivity puzzle" between men and women in STEM has been studied for several decades (Cole 1979; Cole and Zuckerman 1984; Fox 1985; Zuckerman et al. 1991; Long 1992), with findings that although the gap differs in size among fields, women publish less on average than men. The widening of the gap in areas where research is expensive (Duch et al. 2012), as well as the discrepancy in research funding between women and men (Ley and Hamilton 2008) that results in women having smaller labs with fewer people, remain as suggested contributors to the lower publication rates of women.

A few recent examples indicate that despite the increasing numbers of women in most STEM disciplines, gender issues exist at all levels of STEM. A U.S. nationwide sample of 127 male and female science professors picked a man over a woman when asked to choose between two undergraduates with the same qualifications to manage their lab (Moss-Racusin et al. 2012). A study conducted at the University of Washington of a large introductory biology class revealed that male students chronically overestimate the knowledge of their male peers and underestimate the knowledge of their female peers (Grunspan et al. 2016). When students of varying sex and ethnicity asked for mentorship via e-mail requests to 6,500 tenure-track professors at top research universities, those sent by researchers posing as white men were more likely to receive yes responses (Chugh et al. 2014). A study of 85,000 published scientific papers revealed that men and women perform different roles in the labs producing scientific research. Women perform the experimental work involved in pipetting, centrifuging, and sequencing, while men analyze data, conceive the experiments, contribute resources, or write up the study (Sugimoto et al. 2015). In short, gender inequality and disparity in science persist.

Media attention has focused on the dearth of women in science in general, and in the technology sector in particular, despite its rapid expansion and lucrative salaries, women remain especially limited in the management and executive levels of the technology sector. Although

42% of all STEM degrees in the U.S. have gone to women, only 27% of the U.S. STEM workforce is made up of women. Only 3% of Silicon Valley tech startups have at least one female founder (Sposato 2015). It takes women longer to raise seed money (9 months for $1–$5M) than it does their male counterparts (3 months for $1–$5M) (Sposato 2015); perhaps this is because investors who heard pitches by entrepreneurs preferred pitches by a man over identical pitches from a woman (68–32%) (Brooks et al. 2014). A study of performance reviews in technology jobs conducted by Forbes found negative personality criticism in 85% of the reviews for high-performing women, while negative reviews were present in only 2% of reviews for high-performing men.

Juxtaposing the increasing emphasis of global science and technology on innovation with the data on gender participation in the science and technology workforce reveals an additional gender issue: the percentage of women granted patents ranks significantly lower than that of their male peers, and it ranks very low relative to the percentage of women in the STEM disciplines. Given that the percentage and numbers of women are particularly low in technology fields such as engineering and computer science, disciplines that contribute significantly to patents, perhaps it is not surprising that women hold fewer patents than men do. Unfortunately, women patent at significantly lower rates than their male counterparts in all disciplines, including pharmaceutical and medical fields that have high percentages of women, in all sectors such as industry, government, and academia, and in all countries. Only 7.5% of all patent holders are women; 5.5% of commercialized patent holders are women (Hunt et al. 2012).

The focus of global scientific research has shifted from basic to applied research and innovation, for which one of the primary indicators is patents granted. If women scientists and engineers are not obtaining patents at rates comparable to their participation in the STEM workforce and at significantly lower rates than their male peers, then women are not participating in the new areas and directions for science and technology. This hurts women scientists and engineers who are left out of the leading-edge work in innovation. Women are then not seen as leaders in their field, which hurts women financially and in their professional advancement. Commercialization of science can be lucrative, if the patent results in a product that is developed, brought to market, and is successful. Since patents "count" as a marker of success, similar to publications, and may even be required for some bonuses and "fellow" status in some industries, women's small percentages of patents also inhibit their professional advancement. Most importantly, the gender gap in patenting suggests that the global economy may be benefiting less than it might from women's creativity and contributions to new knowledge and innovation.

This edited book by Pooran Wynarczyk and Marina Ranga brings together insights from several scholars from around the globe, aimed at advancing knowledge on the increasing importance of the gender dimension in technology commercialization, hence broadening the current understanding of the dynamics and implications of the phenomenon. The collection of papers in this book clearly demonstrates that the construction of gendered identities within this predominantly male-dominated work environment needs more attention from the academia, industrialists, as well as policy-makers. Incorporating and mainstreaming a gender dimension in research and policy on technology commercialization in the public and private sectors will contribute further to global competitiveness, maximise human capacity and, hence, address, stereotypes and inequalities that currently prevent a greater participation of women in technological advancement in the knowledge-based, emerging and developing economies around the globe.

San Francisco, California, U.S.A Sue V. Rosser

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About the Editors

Pooran Wynarczyk holds a Ph.D. in SMEs and is a Professor and former Director of the Small Enterprise Research Unit at Newcastle University Business School, UK. She is a former elected 'Fellowship Councillor At Large' of the Royal Society for the Encouragement of Arts, Manufacture and Commerce (RSA). She was a shortlisted finalist of the Women in Science and Engineering (WISE) Advisor Awards, 2012 in recognition of the establishment of the Economic and Social Research Council (ESRC) sponsored 'Role Model Platform for Innovative Women and Young Scientists' at Newcastle University. She has published widely in the key areas of the SME sector and entrepreneurship, with particular focuses on: high technology ventures; open innovation; science parks; and young people and women in science and technology (education and career). Her recent publication on open innovation in SMEs has achieved the Emerald Literati Network Awards of Excellence, a 'Highly Commended Paper of 2014'. Two of her previously published co-authored books, 'The Performance of Small Firms' and 'Managerial Labour Markets in SMEs' were reissued in 2016, as part of the 'Routledge Library Distinguished Editions'.

Marina Ranga works with the European Commission's Directorate General Joint Research Centre, in Seville, Spain. Prior to that, she was at Stanford University, as Senior Researcher at H-STAR Institute and Faculty Research Fellow at Clayman Institute for Gender Research. She holds a Ph.D. and a M.Sc. in S&T Policy from the Science Policy Research Unit (SPRU) of Sussex University, UK, and a M.Sc./BA in Chemical Engineering from the Polytechnic University of Bucharest. Her main areas of expertise include: National and regional innovation systems, Triple Helix Systems; Entrepreneurial University, academic entrepreneurship and University-Industry cooperation; Technology transfer and research commercialisation; Technology-driven innovation in higher education; Gender in innovation, technology and entrepreneurship. In these areas, she developed over 30 projects funded by national and regional governments and international organisations, and authored 27 book chapters and articles and over 30 research and consultancy reports. She has also conducted extensive consultancy and advisory work for the European Commission, several UN bodies, OECD, national and regional innovation agencies.

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Introduction Setting the Scene: An Insight into the "Gender Divide" in Science and Technological Advancement

Pooran Wynarczyk and Marina Ranga

Scientific discoveries and technological innovation have been long acknowledged as crucial sources of economic growth, global competitiveness, and social prosperity. As some of the most significant achievements of the creative human mind, one would expect scientific discoveries and technological innovation to be gender neutral by nature. In practice, however, the gendered nature of these processes has raised continuing controversies over time.

In the nineteenth century and well into the twentieth century, women faced significant barriers to science careers, including the construction and perception of gender roles in society, whereby women were expected to marry, raise children, and run the family home, as

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well as the lack of access to education and employment that resulted in financial dependencies on fathers, brothers, or husbands (Hamilton 2000). Women typically had to struggle to be admitted to medical schools or study mathematics (Jaffé 2003), and only upper class women who had the resources to get an education could have easier access to the study of science. Employment opportunities in science, that were typically concentrated in women's colleges, were very limited and came at a considerable personal price, such as heavy teaching loads that were not conducive to publishable research, and the obligation of all women college faculty to be single and resign if they decided to marry, a practice continued well into the twentieth century in some parts of the Western world (Barnett and Sabatini 2009). The exclusion of women scientists from male-only formal educational facilities, scientific institutions or fraternities was a common occurrence, as exemplified by the case of Royal Society: although founded in London in 1660, its statute did not allow women to become fellows until 285 years later, in 1945, as science was considered to be a predominantly male-only profession. Nevertheless, women's relationship with the Royal Society was documented to be far more fruitful than previously thought, with contributions ranging from project team members, colleagues, and assistants, to pioneers of new methods of scientific education, translators, illustrators, and interpreters and, most particularly, "scientific popularisers," according to a recent study (Holmes 2010). Similar practices were at work in the American National Academy of Sciences until 1925, in the Russian National Academy until 1939, and in the Académie des Sciences in France until 1962. Marie Curie was turned down for membership of the Académie in 1911, the very year she won her second Nobel Prize (*ibid.*).

The suffrage movement that emerged in various countries in late nineteenth and early twentieth centuries brought significant changes in women's lives and social representation. After the first granting of voting rights to women in the British colony of New Zealand in 1893, several other countries followed, with limited rights to women in Sweden, Britain, Finland, and some U.S. states by the early twentieth century. In Britain, for example, the Parliament passed the *Eligibility of Women Act* in November 1918, allowing women to be elected to Parliament, and

10 years later, it passed the *Representation of the People Act* that granted the right to vote to women over 30. In the US, the Senate passed the *Nineteenth Amendment* in 1919, giving women the right to vote. Other countries in Europe and beyond granted the vote to women until the mid-1950s. Obtaining voting rights was not just a major civil rights achievement, but also an opportunity for transforming women's citizenship and redefining politics (Andersen 1996), through increased participation in government and in public affairs, political engagement, and civic action (Kraditor 1965; Rob 1996; Hossell 2003).

The suffrage movement also aimed to improve the social perception of women in relation to science and technology, emphasizing the positive evolutionary effects of scientific and technological developments: "*Turning to science for theoretical support, suffragists argued that modern women represented a more highly evolved form of humanity than their predecessors. They regarded machinery as a liberating force that would enable woman to achieve her natural destiny of reaching higher levels through evolution. After all, since science and technology were changing the world so rapidly, surely women must also be improving?*"(Fara 2014). However, this change of perception proved to be an extremely slow process, undermined by Darwinian theories of sex selection and influenced by deeply rooted prejudice in the social perception of women's status, intellectual inferiority, and social responsibilities. It comes thus as little surprise that even decades later, Dorothy Hodgkin, a brilliant scholar who developed protein crystallography and established the structures of vitamin B12 and penicillin, and the only British woman laureate of a Nobel Prize in science in 1964, was referred to in the Daily Mail of the time as "Oxford housewife wins Nobel," while the Telegraph wrote: "British woman wins Nobel Prize—£18,750 prize to mother of three" (The Guardian 2014). Similarly, the work of the British biophysicist Rosalind Franklin, a pioneering X-ray crystallographer that provided an image of the DNA molecule that was critical to deciphering the DNA structure, was not properly recognized, but helped James Watson, Francis Crick, and Maurice Wilkins receive the 1962 Nobel Prize in physiology or medicine (Iqbal 2015).

Some significant progress in the recognition of women's achievements in science and technology came since the mid-twentieth century, once with the emergence of new information and communication technologies (ICTs) that generated new industries, new education modes, such as e-learning and distance learning, new economic and employment opportunities, as well as new work methods and organizational cultures based on improved forms of knowledge generation and sharing. ICTs facilitated an increase in women's share in the total workforce and in their contribution to science and technological advancements, commercialization and innovative processes that result essentially from "brain work". Connectivity technologies such as the Internet and cyberspace "*provide the technological basis for a new form of society that is potentially liberating for women… due to the nature of connectivity technologies, women, rather than men, are uniquely suited to life in the digital age*" (Wajcman 2009: 6). Connectivity technologies are increasingly blurring the boundaries between hard and soft element tools and hence, between men and women, largely due to the fact that they are essentially based on "brain work" rather than "physical ability" (Wajcman 2009; Wynarczyk and Graham 2013).

As some studies identified women as more active users of digital tools than men, ICTs have been seen as a concrete opportunity to address long-standing gender inequalities, including access to employment, income, education, and health services (Hilbert 2011). However, ICTs' capacity to close the gender divide remains limited by uneven ICT access, skills, and infrastructure, as well as many gender-specific inequalities in income, education and literacy, traditional cultural beliefs and practices. Furthermore, the gender and ICT relationship remains an extremely complex one, with some issues that may receive solutions, while many others bring up new challenges. Indeed, as Van Dijk and Hacker (2003: 325) argued, "*Another reason for the complexity of the digital divide is that there are in fact several divides. Some are widening, while others are closing …Technology is advancing, splitting in simple and highly evolved applications, spreading into society and sticking to old and new social differences.*" A broad range of issues require thorough consideration, such as differences in the use of computing technologies by girls and boys/women and men, the different confidence levels and "gendered preferences" they have in doing that, as well as controversies on how ICTs should be used to empower women and enhance individual well-being, how could 'gendered preferences' be considered in the design of ICT products, what policy objectives could help achieve a society without a gender gap, etc.(Tømte 2008).

Women's minority status in certain scientific fields continues to be a major feature of today's scientific community. An important reason for that is the under-representation and continuing dropout of girls and women at every stage of the so-called 'leaky pipeline' in science, technology, engineering, and mathematics (STEM), from school to higher education, and further, to taking up a position in the scientific labor market. Eventually, only a small proportion remain to make successful careers in science beyond the 'glass ceiling' (Greenfield 1994, 2002; Blickenstaff 2005; Muffitt 2014). There are several professional, institutional, and personal barriers that continue to prevent equality for women in STEM fields, although formal discrimination against women has, at least in theory, been removed through equal opportunities legislations and laws in education and employment (Wynarczyk 2006). Such barriers include different childhood exposure to STEM, institutional sexism , stereotyping, prevalence of different role models and mentors, societal attitudes, and assumptions both by and towards women in science, technology, and entrepreneurship, and the deeply rooted culture of the scientific enquiries. As Schumpeter (1934: 84) stated *'All knowledge and habit once acquired becomes as firmly rooted in ourselves as a railway embankment in the earth'.*

The gender bias in academic science is perpetuated in entrepreneurial science (Ranga 2014). The different involvement of men and women scientists' in science and technology commercialization, the incentives and obstacles they face when embarking upon entrepreneurial ventures and their impact on professional careers, have gained visibility in research agendas only over the last decade or so (e.g. Ding et al. 2006; Murray and Graham 2007; Rosa and Dawson 2006; Thursby and Thursby 2005; Whittington and Smith-Doerr 2005, 2008), but still remain largely unexplored. These issues are critical to understanding academic entrepreneurship dynamics and how social capital can be improved, avoiding the perpetuation of current inequalities in academia, e.g., in scientific productivity and earnings from commercializing research (Ding et al. 2010). There is a significant knowledge gap that needs to be filled in this respect, considering the long-standing gender blindness of innovation and entrepreneurship studies, which have usually focused on teams, institutions, and organizations at country or regional levels, and only rarely did they focus on the individual innovator or the gender of the innovator. Ironically, this gender blindness only reinforced the frequently made association between technology, innovation, entrepreneurship, and masculinity (Carter and Kirkup 1990; Cockburn 1985; Massey 1995), perhaps as an extension of another frequent association of engineering and physics with masculinity, in contrast with life sciences which have a more neutral perception (Ridgeway 2009).

One of the most compelling aspects of women's under-representation in science and technology commercialization are Intellectual Property Rights (IPRs). Patents and registered designs, in particular, are widely accepted as a key measure for the overall innovativeness of national economies in the global knowledge-based economy (Kugele 2010). The examination of patent applications and registered designs provide a unique opportunity to assess the contribution made by individuals to technological change, entrepreneurial activities, economic prosperity, personal accomplishments, society, and public life as a whole. A GHK report (2008) suggests that within EU Member States, on average, only 8.3% of patents awarded by the European Patent Office are owned by women, and only 5–15% of high technology-based businesses are established by women. Furthermore, existing research suggests that the majority of university spinouts are based on innovations and inventions in the areas of science, engineering, and technology (SET) that are, historically, male-dominated fields. As fewer women participate at the 'cutting edge' of SET or hold senior position in the scientific departments, they are unlikely to be the founders of spinout companies (Rosa and Dawson 2006). Moreover, in most countries around the world, the percentage of women obtaining patents is not only less than their male counterparts, but it is also below the percentage of women in any STEM disciplines (Rosser 2009). As Rosser (2009: 1) states, "*This hurts women scientists and engineers who are left out of the leading edge work in innovation. Women are then not seen as leaders in their field, which hurts women financially and in their professional advancement.*"

One of the main reasons for the 'invisibility' surrounding women as innovators and inventors stems from the lack of academic evidence surrounding their contribution. "If Steve Jobs had been Stephanie Jobs, would anyone have ever heard of her?" is a question often heard in Silicon Valley and other environments with a culture less welcoming to women, which brings attention to the glaring lack of women in technology and entrepreneurship (Abrams 2015). Moreover, several theories in the existing literature, including STEM, leaky pipeline, technology, and feminist, focus mainly on the identification of underlying barriers that generate gender imbalance in these fields and undermine the contributions made by women to technological advancement (Wynarczyk and Marlow 2010). In fact, historical research shows that women have been behind a much larger number of innovations and inventions and patents than traditionally given credit for (Hamilton 2000; Fara 2004; Jaffé 2003, 2010). According to Jaffé (2003), there is a hidden history of "ingenious women" going back nearly 600 years, starting with the first English patent granted to a woman in 1637. The original research carried out by Jaffé (2003) that included a sample of English, British, and US patents by women in Europe and North America revealed over 500 female patent holders between that first patent (1637) and the outbreak of World War I in 1914.

Women's contribution to male-dominated work environments, such as the production and management of technology, or the transfer and commercialization of new technologies, is little explored, although it has become more and more evident in recent years that rising numbers of women scientists leave academia to take up careers in high-tech entrepreneurship. The gender dimension in the management of technology firms (especially at the mid- to senior management level, which is a critical juncture for women on the technical ladder as the point of convergence of several gender barriers) is a major issue, as well as the integration of female users' needs into research and development processes, and product development. Only few companies consider adaptation of their products to female users' needs and preferences at an early stage of product design. It is worth mentioning in this respect the example of the Volvo YCC ("Your Concept Car"), which was a concept car made by Volvo Cars upon an initiative taken in June 2002 by an all-women