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TECHNOLOGY, COMMERCIALIZATION AND GENDER

A Global Perspective

Technology, Commercialization and Gender

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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 team of engineers and executives, targeting the most demanding premium customer: the independent, professional woman.[1] The concept car was presented at the 2004 Geneva Motor Show, and demonstrated that women want everything that men want in a car in terms of performance and styling, "plus a lot more that male car buyers have never thought to ask for."[2] Although Volvo never actually produced this car, many of the ideas introduced by the female designers have been taken up in more conventional cars produced by the group.

There are also many questions related to how technology management and commercialization develops as an occupational field, what a 'career' in this area means, and what gender differences does it encompass; what best practices of gender equality exist in technology commercialization organizations, and how can they be widely disseminated to benefit the work and careers of women; and what is the impact of gender segregation in scientific research on technology entrepreneurship.

The contribution of women to technology and innovation commercialization for economic, technological and social advance is demonstrated by only few extraordinary examples and case studies. Significant and ground-breaking achievements of women in these fields are often eclipsed by the general presumptions that women are more likely to hold positions in low-skill and low-achievement scientific sub-sectors, which has led to the assumption that they have little impact and restricted contribution on overall innovation capacity and competitiveness (Wynarczyk and Marlow 2010). If successful, women in these fields are neither visible, nor seen to be benefiting from a rewarding and progressive career and, thereby, making an important contribution to the technological capacity and society, they are unlikely to be able to contribute to further recruitment, retention and progression of women that is imperative to meet the increasing demand for the highly skilled workforce and new emerging industries.

On these grounds, it is evident that the construction of gendered identities in technology management, transfer, and commercialization needs significantly more attention from academic scholars, university, and business leaders alike, as well as policy-makers. This edited book aims to fill a gap not only in the knowledge, but also in the practice of such issues at an international level, by bringing together a collection of papers by several scholars in the United States, Mexico, and Europe that can advance awareness on the increasing importance of women and technology commercialization and broaden the current understanding of the dynamics and implications of the phenomenon.

In its eight chapters and a case study, the book addresses a broad range of issues, as follows:

In Chap. 2, Kathinka Best, Marie Heidingsfelder, and Martina Schraudner focus on the gender-dimension integration in knowledge and technology transfer (KTT) in Germany. Over the past few years, increasing political pressure and funding initiatives have addressed the gender imbalance in KTT in Germany, and contributed to increasing gender awareness in the KTT community. However, an in-depth analysis of gender integration in KTT and the effectiveness of the initiatives and positive action measures is still lacking. Based on a combination of a comprehensive literature review and some 22 interviews with decision-makers and (former) scientists, the authors have established an original KTT model in order to fill the gap in research. Their findings reveal that the gender dimension has not yet been adequately integrated, although a cultural shift in KTT is gradually emerging. They conclude that stereotyping views and assumptions continue to greatly inhibit successful integration of the gender dimension, as a result of the fact that traditional ideas about gender attribute less technical competence to women.

In Chap. 3, Humberto Merritt and Maria del Pilar M. Perez-Hernandez explore the patenting and research commercialization activities of Mexican female scientists at the School of Biological Sciences of the National Polytechnic Institute (ENCB-IPN), which is one of the country's most prestigious academic institutions, with a long tradition in teaching and scientific research for women life scientists. As in Mexico, biotechnology is one of the few fields involving large numbers of women scientists, this chapter examines how these women scientists interact with their male colleagues in patenting and commercializing biotechnology research. The authors find that most ENCB female scientists tend to patent in collaboration with male scientists, while only a handful of them patent alone. The authors also discuss how this situation is dealt with, and what challenges there are in pursuing an entrepreneurial vocation in the Mexican scientific milieu.

In Chap. 4, Elba Mauleón and María Bordons, present a unique study of Spanish technological activity by gender through the analysis of patent applications offered by the European Patent Office (EPO). In Spain, women remain a minority in technological activity as measured by their presence as inventors in patent applications filed with the EPO during 1999–2007. For the purpose of their study, patents with at least one Spanish inventor that were applied for at the EPO in the 1999–2007 period are analyzed by gender and type. Binomial logistic regression is used to unravel whether female presence could be predicted based on several variables, including number of inventors, thematic classification of patents, institutional sector, and publication year. The dependent variable "female presence" is measured on a dichotomous scale—"any female inventor" or "no female inventor." The overall findings reveal that patent-based indicators by gender are useful to monitor the presence of men and women in technological activity. This study provides evidence of the uneven distribution of female inventors across institutional sectors, demonstrating a relatively higher presence of women in the public sector (e.g., University) than in the industrial sector and among individual applicants.

In Chap. 5, Slavica Singer, Nataša Šarlija, Sanja Pfeifer, and Sunčica Oberman Peterka combine different theoretical angles (theory of firm growth, entrepreneurship, inclusion, macroeconomic aspects of using resources) with a gender perspective to examine several gender patterns of businesses with growth potential in Croatia (innovative products, innovative technology, and competitiveness). The authors draw on aggregated Global Entrepreneurship Monitor (GEM) data from the 2003 to 2013 period to demonstrate that firm growth both for early-stage businesses and established businesses is influenced not only by firm size, but also by a large number of other parameters that depend on the gender and the phase of the venturing process, such as personal demographics, personal attributes and societal values, firm demographics and business innovation strategies, as well as individual motivations for entering the venturing process. All these parameters are important to consider in improving the innovation and entrepreneurship capacity of Croatia, a country with high unemployment that is currently in an active process of catch up with the more developed economies of the European Union.

In Chap. 6, Malin Lindberg and Anders W. Johansson compile existing studies on gender-sensitive business counselling—an increasingly common policy measure in Western economies to increase the number of women entrepreneurs—and compare them with an empirical case in Sweden, carried out to determine whether this kind of counselling can change the gendered pattern and understanding of entrepreneurship. Eight components and three effects are distinguished, some of which are specific to gender-sensitive business counselling, while others are similar to general counselling methods, requiring symmetrical relations between counsellor and client and the client's active role in order to contribute to changes in the gendered pattern and understanding of entrepreneurship.

In Chap. 7, Catherine Ashcraft and Joanne Cohoon report findings from two studies: one on female rates of patenting and one on female authorship of computing conference papers. They demonstrate that while women's participation remains low, especially in terms of patenting, important increases have been made over time. They also examine variation in the rates of patenting and authorship across companies and across conferences, ultimately identifying some important implications for increasing women's meaningful participation in key commercial and intellectual aspects of computing.

In Chap. 8, Kathinka Best, Michael Rehberg, and Martina Schraudner suggest a collaborative, user-centered ideation phase that includes gender aspects from the very beginning of the research and development process. Based on a case study from Fraunhofer's *Discover Markets,* they identify five rules for participative innovation processes, allowing for the integration of women's wishes and needs. The integration of gender aspects is part of the Responsible Research and Innovation (RRI) framework. The suggested participative process offers thus the chance to combine commercial success with (social) responsibility.

Finally, in Chap. 9, Patricia Fara provides a case study of Hertha Ayrton, a British engineer, mathematician, physicist, and inventor, who was awarded the Hughes Medal by the Royal Society for her work on electric arcs and ripples in sand and water. Although her work spanned the second half of the nineteenth century and the first two decades of the twentieth century, the obstacles she faced still challenge the women scientists of the twenty-first century. By presenting her life in two different versions—first as a stereotyped heroine and then as a scientific outsider—the case study highlights how strongly gender can affect the perceptions of ability and career success.

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2

The Gender Dimension in German Knowledge and Technology Transfer: A Double-Edged Sword

Kathinka Best, Marie Heidingsfelder and Martina Schraudner

Introduction

> A relatively equal gender balance in technology transfer masks the structural gender bias of German society and becomes a double-edged sword. (Ranga and Etzkowitz 2010)

Effective knowledge and technology transfer (KTT) is a crucial element of a nation's innovativeness and economic position (Teece 1977; Poirson 2013). In Germany, substantially fewer women than men participate

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in research and development (Frietsch et al. 2012), which weakens its capacity for innovation (European Commission 2013b; Commission of Experts for Research and Innovation 2014). In a similar way, women's potential remains largely untapped in many other industrial countries (Ranga et al. 2008; European Commission 2009)—"a waste of human resources" (Ranga et al. 2008, Research Global, 8(2): 5, 2008).

Studies have shown several advantages for mixed-gender teams inside and outside of research and development—among other things, a significantly higher likelihood of introducing an innovation (Østergaard et al. 2011), more constructive interactions (Kochan et al. 2003), reduced communication barriers (Schone et al. 2010), and greater analytical effectiveness (Woolley and Malone 2011). Higher success was observed, for instance, by measuring patent citation rates (Ashcraft and Breitzman 2007) and the impact of Ph.D. holders' commercial work (Bunker Whittington and Smith-Doerr 2005). While industry has increasingly recognized the economic benefits and the potential for creativity and innovation of mixed-gender teams (Thomas and Ely 1996; Gratton et al. 2007), in 2011, <25% of 450,000 researchers were women (Frietsch et al. 2012). The few existing studies all also indicate low proportions of women in KTT, which decreases further with each successive stage of the process. For instance, women usually make up between 3.5 and 8.0% of all patent applicants in technology start-ups (Achatz et al. 2010; Busolt and Kugele 2009; Schone et al. 2010; Commission of Experts for Research and Innovation 2014).

Potential explanations for the existing imbalance can be found in a range of disciplines and in particular in sociological and feminist literature (e.g., Sonnert and Holton 1995; Connell and Messerschmidt 2005). The few existing studies, which focus primarily on Europe and the US, establish common "gender patterns" in technology transfer that disadvantage women in several industrial countries (Ranga et al. 2008; Ranga and Etzkowitz 2010). In their analysis of technology transfer organizations in Germany, Achatz et al. (2009, 2010) established that organizational and work structures and cultures disfavored women's success. Within the last 4 or 5 years, however, increasing political pressure (30% quota for female managers) and funding initiatives have been directed at mediating the gender imbalance in science—and in German

KTT. These dynamics may have contributed to increasing gender awareness in the KTT community; there has not been a recent in-depth analysis of gender-dimension integration in KTT.

Seeking to fill this gap and to analyze possible changes of KTT cultures and managers' mindsets, we therefore pose our research question: To what extent is the gender dimension integrated into KTT by decision-makers and (former) scientists? In order to answer this question, we first established a KTT model that is sensitive to current (external) influences, such as market pull and societal changes, as well as the current understanding of the gender dimension.

This chapter presents the theoretical and empirical background that guided our research, our method, and our findings. It concludes with a summary, implications for further research and potential recommendations for decision-makers, both inside and outside of Germany.

Empirical and Theoretical Background

Knowledge and Technology Transfer: Analytical Model and National Specifics

Occurring between the scientific and the business communities, knowledge and technology transfer, or KTT, aims to transform theoretical findings into highly marketable products. KTT consists of complex exchanges of ideas, discoveries, and methods between research institutions, industry, and the public. To make innovations viable, we assume that public preferences (of both women and men) must be accommodated in the full variety of their needs, preferences, and perspectives, both gender-specific and otherwise (Meißner and Sultanian 2007; European Commission 2013b). For the purposes of our research, we have developed our own process model; its stages and participants are shown in the following illustration.

Transfer has conventionally resulted in what is known as *technology push*, or the transformation of scientific findings into publicly accessible products. One relatively new and promising form of transfer is *market pull*, in which lay ideas and experiences initiate prospective scientific

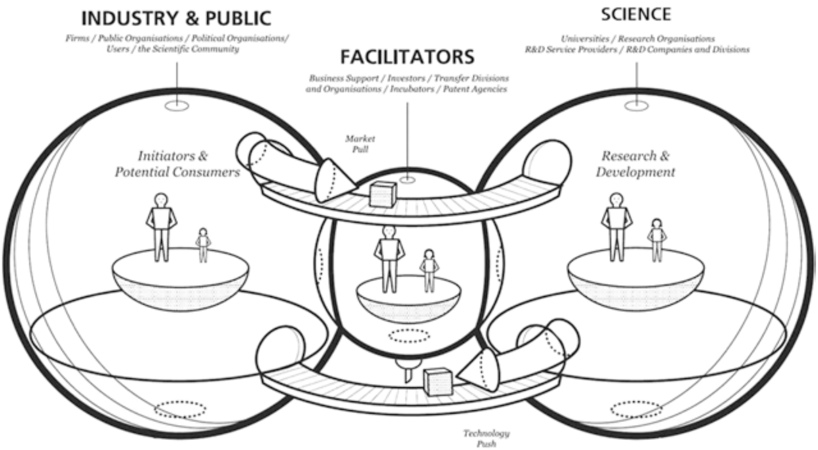

Fig. 2.1 Stages and participants of knowledge and technology transfer. *Source* Kline and Rosenberg (1986), Bessant and Rush (1995), OECD (1996), Reinhard et al. (1996), Bozeman (2000), Meißner and Sultanian (2007), Barjak (2011), supplemented by ideas from Jolly (1997), von Hippel (1988)

and technological advances; this maps onto the notions of "lead users" (von Hippel 1988, 2005) and "open innovation" (Chesbrough 2003). By adhering to the needs and values of laypersons (both gender-specific and otherwise), market pull can help orient innovations toward public preferences and foster innovation viability (Schraudner and Wehking 2012; Heidingsfelder et al. 2015). To date, however, this promising form of KTT has only been implemented in a small number of pilot projects. What makes technology push useful, the currently more widespread direction of transfer, largely depends on the male and female knowledge carriers and decision-makers in KTT.

KTT participants roughly fit into the following three major groups: (1) scientific organizations, (2) transfer organizations or facilitators, and (3) both industry and the public (see Fig. 2.1). Transfer (oriented) organizations, or TOs, are at the center of this article and include transfer departments at research organizations and universities and research and development (R&D) providers such as small-scale R&D service organizations and companies' R&D divisions (Achatz et al. 2010; Tintelnot et al. 2013). The wide range of TOs often support the entire KTT process by mediating between scientific, industrial, and commercial organizations and helping identify, shape, and implement transfer ideas (e.g., Barjak 2011). Their interface function is particularly interesting for research on the gender dimension in KTT. Our KTT model provides an accessible starting point for exploring the gender dimension in KTT.

Interwoven national agendas and domestic shareholders' and organizational specifics partly influence KTT's trajectories and outcomes (Lundvall 2010). Given that we focus on the individuals involved in KTT, these processes are largely neglected within the scope of this article.

The Gender Dimension

> Women's potential is indispensable for securing and improving performance and innovative capacity in research and science. (The German Council of Science and Humanities 2012, p. 5)

In Germany, the scientific community has increasingly recognized the promotion of gender equality as one of its key responsibilities to the public and as a necessary contribution to the quality of its research. These tendencies match one of the six key principles of the European Commission's funding framework, Responsible Research and Innovation, and notions of Horizon 2020 (European Commission 2011, Article 15). National standard-setting institutions such as the German Research Foundation (2008) and the United States' National Science Foundation (2009), recognize "gender aspects", also referred to as the "gender dimension" or gender, as an important component of quality research (The German Council of Science and Humanities is similar in this regard). Scientific case studies of *Gendered Innovations*, a state-of-the-art European-American project, support recognition of the gender dimension to eliminate blind spots in research content and to foster new products, services, and infrastructures.

Additional funding to support women in science includes, among others, €300 billion provided by Germany's Federal Ministry of Education and Research to promote female professors and excellence in science (2006–2017) and €2.3 billion in research funding provided annually by the German Research Foundation is connected to the successful implementation of the Foundation's standards. These "research-oriented standards on gender equality" published in 2008 aim to enhance (1) Female participation in science, while improving (2) Structural and (3) Personnel policies.

For the purposes of our analysis and in order to make the gender-dimension construct accessible, we distinguish between its quantitative and qualitative components.

1. *The quantitative component* refers to the gender compositions in groups and structures, which are involved in or related to KTT; these can include teams, decision-makers, the scientific community and its parts, funding organizations such as financial institutions and venture capitalists, and finally, a whole nation. According to the critical mass theory (Kanter 1977), as the percentage of a certain subgroup within a larger group reaches about 30%, this subgroup is no longer perceived as a minority and can "affect the culture of the group." The quantitative component can, therefore, be measured by analyzing data on women in KTT.

Increasing the proportions of women beyond a certain threshold, therefore, does not guarantee the full utilization of gender potential (Williams and O'Reilly 1998; Jackson et al. 2003; Horwitz and Horwitz 2007). Full utilization of untapped "gender potential" (with the aim of increasing Germany's innovative capacity) can only be achieved by "fully integrating" the gender dimension qualitatively (Kanter 1977, cited in Acker 1990).

2. *The qualitative component* refers to the quality of gender integration in KTT. According to gender-sensitive organizational theory, organizations are not neutral. Instead, gender norms as well as gender assumptions and stereotypes create the foundation for organizational processes while at the same time reproducing gender (Acker 1990). Additionally, occupations and job types have been identified as gendered, i.e., based on assumptions of male and female (Britton 2000). Within every organization, gender is therefore implicitly inscribed into processes but "covered up by equality" (Benschop and Dooreward 1998). Research shows that, while the general organizational discourse is based on equality of opportunities, stereotypical assumptions are

interwoven into ideas of qualification, innovative capacity, and performance and form a gendered substructure within organizations (Acker 1990; Billing and Alvesson 2000). Gender is naturalized and essentialized, and the ideal jobholder is based on maleness. Within these contexts, gender subtexts systematically (re)produce gender distinctions via sets of arrangements (Benschop and Dorewaard 1998), among other things in the form of interpretative repertoires. Women are, therefore, unacceptable by definition (Acker 1990).

The gender dimension is considered fully integrated in KTT when each of its components is integrated. In other words, when (1) groups of participants are fairly gender-balanced and (2) when the gender dimension is critically reflected and completely factored into organizations and individual processes (Acker 1990; Smith 1987). This integration manifests itself in the consideration of aspects of gender, the selection of research topics, and particularly in the integration of diverse perspectives (of men and women) and a not gender-biased definition of gender roles in relation to innovation, technical capacity, affinity for technology, and career opportunities (Sonnert and Holton 1995; Faulkner 2006; Ranga and Etzkowitz 2010).

The major purpose of such full integration is to foster quality of research and the global viability of transfer products. Such fostering has been equally emphasized by political initiatives (European Commission 2011), in theoretical findings (Ranga and Etzkowitz 2010; Bührer und Schraudner 2010), and in practical applications (European Commission 2013a). Market pull approaches are increasingly accepted as a means to accommodate public preferences and expand the realm of what is technologically and commercially possible (European Commission 2013a). Such alternative means of qualitatively integrating the gender dimension into KTT will be considered in the following.

Method

Our method combined a comprehensive literature review with key informant interviews (following, e.g., Eisenhardt and Graebner 2007). Whereas the literature review allowed for a retrospective analysis of the gender dimension in KTT, the key informant interviews were intended to provide information from multiple perspectives and sources on intra- and inter-organizational settings in KTT (Kumar et al. 1993). The key informant interviews delivered insights on socially constructed identity and reproduction mechanisms in KTT (Lamnek 2008), including on their gender basis and the underlying logic (Acker 1990). The qualitative interview data are the focus of our research design. The multidimensional approach helped us comprehensively explore our research question and assess past, current, and possible future developments.

Literature review. We first reviewed existing publications from a range of disciplines to refine our understanding of the gender dimension in KTT. These disciplines included the natural sciences, engineering, economics, social sciences, psychology, innovation research, entrepreneurship research, gender studies, and research on small group behavior. We searched in published books, databases, and online journals for peer-reviewed publications and publications printed by renowned publishers. By combining certain keywords (related to knowledge and technology transfer and gender), we selected 350 publications for further review. We then comprehensively analyzed the abstracts of these publications and included 120 publications with relevant insights into the gender dimension in our pre-final selection (search strategy according to Hart 1998; Isaac et al. 2009). The final selection of relevant scientific publications comprises 60 titles published between 1999 and 2014. According to Hart (1998), these reviewed articles were evaluated with regard to important variables relevant to women in KTT, new and/or gender-related perspectives, relationships between ideas and practice, and the structure of our subject.

Supplemented with KTT-related gender statistics, publications on national and European political resolutions, programs, and initiatives, the literature review allowed for analysis of the quantitative component and for developing theory-based interview guidelines.

Key informant interviews. For our interviews, we selected 22 specialists based on theoretical sampling criteria (Eisenhardt and Graebner 2007): eight (former) researchers/scientists involved in KTT, eight TO specialists, and six senior managers. All interviewees either worked (formerly) as scientists or occupied KTT leadership positions in science (e.g., head of a transfer-related business division), in transfer organizations or among shareholders (e.g., government employees). Interviewees were selected for their profound, long-term experience in KTT and their power to either set KTT agendas (as senior managers) or for their active involvement in the process, often in a supervisory position (Gläser and Laudel 2010). To avoid biases, the sample was balanced with regard to gender (Acker 1990) and comprised various age groups (Jørgensen et al. 2009).

Each interview lasted approximately 90 min. The semi-structured guidelines encouraged the interviewees to speak freely and at length to capture their individual identity, femininity, and masculinity constructs in light of their respective organizational settings. The sets of questions covered individual background and professional development, the specifics of interviewees' teams and organizations with respect to processes, practices, and behaviors, and general questions regarding understanding and individual notions/definitions of gender, KTT, and possible interrelations. Theoretical saturation occurred (Lamnek 2008).

Each interview was recorded, transcribed, and coded by two researchers in order to increase the reliability of the data. With the aim of theory building (Eisenhardt and Graebner 2007), we analyzed the interviews with a special focus on statements regarding perception of self and others, gender-typical behavior, and gender-typical experiences within KTT departments in science and research organizations as well as other transfer organizations and transfer teams.

We deducted theory-based categories, which reflected the findings of the literature review, and inductively expanded and amended them along the (empirical) perceptions of the participants. This produced a category system for our qualitative content analysis (Mayring 2010), which we used to aggregate and condense the interview data accordingly—the interview data was categorized along, for instance, individual professional development, gendered behaviors, team interactions, organizational practices, and norms (Schein 1990). By structuring the aggregated and condensed data in their respective context (Mayring 2010), we were able to establish typical patterns and to identify illustrative (rather than representative) statements (Parker 1992), as presented in the next section.

Findings

> Why would we need to pay special attention to women? You have to be really careful with things like that. (Male stakeholder)

Most of the studies and statistics address the gender dimension in science either relatively abstractly or in a way that is not KTT-specific or else they look at very specific elements of the process. While the quantitative components of the gender dimension have already been examined by various actors on various levels (albeit usually indirectly), the qualitative components have scarcely been addressed and the work that has been done has come exclusively from social scientists. As a result, there is still no single, cohesive explanation for the quantitative decline in women's participation along the way. For that reason, we analyzed the qualitative components by investigating individual views of gender-specific perception and negotiation processes that determine the integration of the gender dimension in the KTT used by women and men in the social sciences.

Selected, typical statements intend to illustrate the argumentation. The sexes (for reasons of simplicity, male and female) and positions (specialist, transfer manager, (former) scientist) of quoted interviewees are revealed for each quote.

The Quantitative Gender Component

On the organizational level, no comprehensive national or cross-national studies on women's participation in KTT exist. In order to estimate the situation in Germany and, to some degree, compare it to the situation in Europe in general, we examined certain related percentages, which we selected based on our literature review. The following chart summarizes the percentages taken into account when analyzing the quantitative component of the gender dimension (Fig. 2.2).

Our evaluation of the available statistics indicates that the ratio of women in KTT in Germany is lower relative to other European countries, decreases with each successive stage of the KTT process, and is

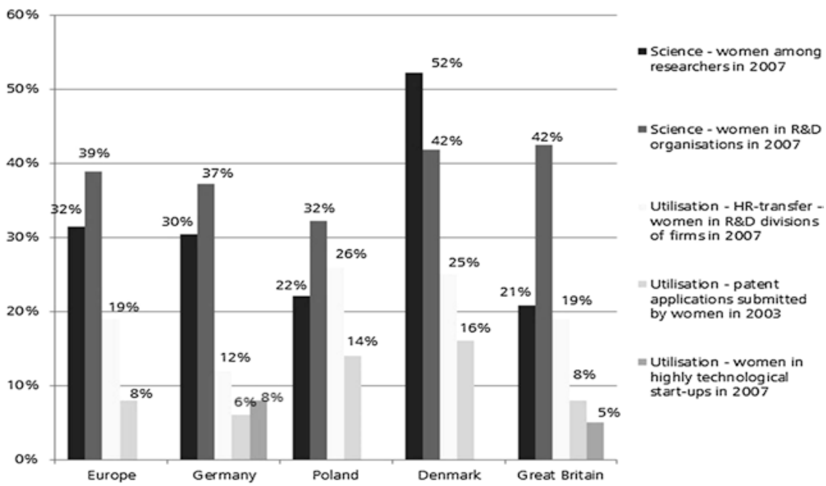

Fig. 2.2 Percentages of women in KTT in selected European countries. *Sources:* Eurostat (2014a, b, c), Busolt and Kugele (2009), European Commission (2008), Metzger et al. (2008)

probably low with respect to key positions. Both the literature review and the interviews indicate that the degree of qualitative gender integration in KTT is rather low. Overall, the respondents confirm a female participation rate of 10–30% in transfer organizations.

The Qualitative Gender Component

> We haven't really thought about that yet. You are probably asking the wrong person. I did find [it] very interesting, though. Gives you a change of perspective. We've never looked at it that way before, kind of just went with the flow. (Male transfer manager)

The very few relevant studies all indicate that the early stages of transfer processes, such as the identification of prospective research trajectories, do not yet sufficiently address the qualitative component of the gender dimension (Bührer and Schraudner 2006; Pollitzer 2013).

The interviews reflect this. Two characteristics stand out as a common thread in the key informant interviews: (1) There seems to be a "common" KTT culture in the large TOs that is supported by regular exchange among decision-makers and that is characterized by a high degree of gender blindness and (2) while some of the female interviewees reflected on the meaning of gender in at least their own development, most of the male participants thought about gender-specific issues only minimally or not at all. This was apparent not only in explicit statements about comprehension of the gender dimension ("That would be a question mark," male transfer manager) but also in observations of various interpretive models where comprehension and the role of women in KTT are concerned in general: While more than half of the participants posited equal treatment of women and men at the start of the interview, they described competencies, patterns of behavior, and career opportunities in issue-specific, gender-stereotyped ways upon further questioning during the interview. Many of the participants presented different interpretive repertoires (Wetherell and Potter 1988) simultaneously with respect to the gender dimension without consciously perceiving their own ambivalence.

Both genders' views of women and men in KTT are presented below. Particularly, large differences are apparent here within and between genders. The focus here is on personal characteristics and views of the gender dimension.

Definition of the Gender Dimension from the Perspective of the Interviewees

> The disembodied worker is definitely not neutral, but produces and is produced by gendered subtexts in organizations. (Benschop and Dorewaard 1998)

While the theoretical derivation of the gender dimension is a comprehensive (quantitative and qualitative) concept, the interviews show that its practical application has only been partially realized as yet: On one hand, aspects such as genders' relevance as a testing and assessment

Fig. 2.3 Interpretative repertoires of women and men in KTT

criterion in science are obviously being implemented: however, they are currently classified as "inconceivable". This includes specifically addressing women's markets. According to almost all the interviewees regardless of gender, decisions regarding product orientation and target groups are made by the mostly male b2b employers without including the interviewees. All the participants appeared to be equally open to factoring in diverse perspectives at first, which was frequently reflected in decision-making structures that were described as participatory. But upon further questioning, various gendered subtexts (Benschop and Doorewaard 1998) and types of subjectivity had an effect on the contributory and decision-making levels (Acker 1990). These in turn produced different results in negotiation processes and in the various organizational structures (Dick and Casell 2002). Figure 2.3 shows the different concepts that interviewees supported with noticeable frequency broken down by group (although they could coexist in the mind of a single person) (Wetherell and Potter 1988; Talja 1999).

While the official organizational logic supports openness with respect to the gender dimension and gender equality (K1), inquiries (particularly where female employees and older men are concerned) reveal gendered structures (K2; Connell and Messerschmidt 2005). For example, men aged about 45 and older were particularly likely to ascribe traditionally female patterns of behaviour when they spoke about their female employees, professional contacts, and KTT colleagues. This group forms an old boys' network within the KTT culture described above, in which traditionally male modes of behavior are part of the self-definition ("It's not that a woman couldn't do it. It's just a very, very male-dominated world," male transfer manager). The interviewees also ascribed traditionally male patterns of behavior exclusively to men in this age group. Younger men described themselves as "more sensitive" or "more cautious" but without examining those characteristics in light of traditional roles. By contrast, gender-specific self-attributions were mostly linked to hierarchical level, meaning that female managers (likewise without seeing any contradiction with gender-specific roles) ascribed traditionally male attributes to themselves.

Apart from neutralizing typically male behavior, many participants saw benefits ("atmospheric benefits" as well as greater structuring of processes and procedures, particularly in more openness) in introducing women into the KTT teams. Female managers, therefore, link an opportunity to the gender dimension relatively often and, unlike the male managers who we interviewed, were able to identify concrete advantages to their greater involvement, for instance via market pull approaches.

> But there too the tinkering engineers are all men. The idea that the customers are female is undoubtedly new there. Because suddenly there's the question of who is deciding what to buy. … And so we come back around to the women. (Female transfer manager)

According to the interviewees, openness requires new ranges of topics to be created and the integration of diverse perspectives, which may be necessary for innovation. The following gender comparison shows the constitutive negotiation process and intersectionality within and between genders with respect to the gender dimension (Davis 2008).

Women in KTT: Professional Position is Crucial

More recent studies as well as older ones (e.g., Wimbauer 1999; Bührer et al. 2009) show that women in the highly competitive scientific cultures of German research institutions feel that they are often not accepted or valued. Most of the women who participated confirmed that assertion. However, people who work in KTT (more so than in “pure” science) are concerned with the “communication” of scientific results. Nonetheless, women, who are often perceived as “social, sensitive, and communicative” (Achatz et al. 2010), *cannot* thereby positively set themselves apart in KTT, according to many of the participants. They are still hired mostly in administrative areas.

Among the interviewees, whether or not women adopt these traditional, stereotypically “female” characteristics depends primarily on their position. Female interviewees with leadership positions were consciously tough, venturesome, and confident. Those characteristics typically carry masculine connotations (Connell and Messerschmidt 2005), but they were common traits among the female KTT managers who participated in the survey. Typical statements include, “When I do something, something happens” (female former scientist). These women gladly augmented this with additional self-characterizations, such as “very freedom-loving, independence-loving” or “entrepreneurially oriented” (as men according to Achatz et al. 2010) and provided biographical examples:

> One reason [for coming] was that I am also such an entrepreneurially oriented person. Because there is nothing. There is no position, there is no idea, there are no resources. (Female TO manager)

> For me it was always that I thought I would always get through. Regardless of what happened. (Female former scientist)

> I never had trouble getting respect or whatever even outside. … It was much harder at the university. (Female TO manager)

Women in managerial positions also spoke confidently about the respect they have received. Professional biographical elements that they identified, such as their parents’ home or their education, point toward a relatively high frequency of socialization in male-dominated and/or technologically oriented environments. Macha and Klinkhammer (2000) and Geenen (2000) have already identified this as typical of successful women in the MINT disciplines. The fact that the women who were interviewed were not discouraged by a competitive environment and frequently proved to be indifferent to other people’s appreciation also had a career-enhancing effect. They were happy to emphasize their felt and consciously experienced mental independence from social norms. The following quote illustrates this with reference to the discussion of social ascent/descent, which is described as incidental:

> Financial security … has never been an issue for me. So my favorite saying is that when everything stops working, that's when I come through as the cleaning lady. (Female former scientist)

Women in male-dominated areas typically have to fight for influence and for their positions (Acker 2006; Billing and Alvesson 2000). Many female managers have explicitly addressed discouragement by both male and female colleagues but simultaneously dissociate themselves from the interpretation that they are being discriminated against as women: "The idea that [as a woman] someone might not give me credit was never up for discussion either" (female TO manager). Instead of feeling disadvantaged, they deliberately make us of their status as tokens (Zimmer 1988). They also perceive opportunities to exercise influence regardless of how they come about—even if they are based on quotas (which are currently pursued on a voluntary basis): "It makes no difference to me at all why they're inviting me [to join the committee]. They're doing it. And then I can get involved" (TO manager). At the same time, the women we interviewed were satisfied with their high workload of approximately 50–70 h per week (comment from a leading female manager: "It's within reasonable limits"). Alongside this conscious rejection of traditional roles, there are also gender-specific attributions among women in leadership positions as the example of communication makes particularly clear. According to these women, they are much more "intuitive" and "better" among women, as the following quote illustrates:

> Yes, more intuitive. There's not all that much to say about it. Maybe it's like that among [men] as well. But in any case, it's not between men and women. That is absolutely clear. Totally clear. (Female former scientist)

In sum, both the work-history elements and the self-assessment of women in leadership positions provide information to the effect that success factors in KTT are male-oriented (Acker 2006; Billing and Alvesson 2000). The male participants confirmed that perception.

At the same time, female managers tend to be unaware of traditional role models, according to which women dedicate a great deal of time to their families and, for example, spend about a year (standard in Germany) with their child after giving birth. As such, they also emphasize the difference between themselves and "normal" female KTT workers:

> [Many women], how can I say this, don't even allow themselves a babysitter. … And I – I've said, no – I'm doing a fulltime job here and I'm traveling in Europe. (Female transfer manager)

Female workers of the same age (between 38 and 59) reveal completely different attributes. In comparison with emancipated managerial figures, it is striking that these women ascribe traditional female characteristics ("emotional", "less rational", "weak-willed", etc.) to themselves and other female workers, as the following statement about the role of women in science illustrates:

> Scientific thinking among men is sometimes a bit different that way. They look for reasons so they can verify things while women might sometimes say, "Yeah, I think that's the right way, that's how I feel, that's my experience." … People often say that women sometimes look at things more emotionally, even in science. (Female TO)

The gender-stereotyped behavior that women try to fulfill is a career disadvantage for them (Achatz et al. 2009), even though some interviewees also named advantages to femininity that were success factors:

> Women often taken on the role … of mother hen, I would say, so they really operationally keep the whole thing together. And they recognize interpersonal tensions early too, but can also organize things very efficiently. (Male shareholder)

The higher degree of structure and the production of functionally significant "cohesion" (see also Ranga and Etzkowitz 2010) are ostensibly positive but they indicate persistent stereotypes that in aggregate have a negative impact, as demonstrated for example by frequently asserted "typically female" risk aversion, which is associated with lower visibility.

> Women lack courage. I think they don't – they don't have self-assurance, self-confidence. … Although they probably have great ideas too. (Female transfer manager)

In sum, observation of women in KTT shows that women in managerial positions systematically display various and more masculine-connotative characteristics than KTT employees. They do not identify with socially ascribed female gender roles but with the ideal of their workplace. Successful women are still the ones who exhibit male-connotative characteristics as "showpieces" (Benschop and Doorewaard, Organization Studies, 19(5): 792, 1998) and deny gender-based discrimination. They meet the requirements of the "disembodied job model," which are oriented to male career backgrounds (Benschop and Doorewaard 1998). The "gender filter" (1995) (which prioritizes masculine, "linear" work histories) has a similar effect here as in science. Despite more open organizational structures, women in KTT do not have more career opportunities available to them.

Men in KTT: Perceptions?

> The head of an institute is a small king. (Male scientist)

In KTT, men are still the majority in a relatively homogenous, exclusive group of decision-makers who, according to statements by women in management positions, only reluctantly integrate (female) rivals and their views and/or support their ideas and/or changes initiated by new people. According to most of the interviewees, standard, stereotypically male, mildly aggressive behavior is only diminished when women are no longer perceived as tokens/isolated phenomena (Kanter 1977; Zimmer 1988).

> Communication among those of us on the executive board has gotten better since a second female director was integrated. And the results are

> better because of that, of course. Because just a lot of meaningless petty wars that used to – what people always like to call cockfights don't happen anymore at all. Or if they do, everyone looks annoyed and the new colleague learns quickly, hmm, that's not okay. (Female TO manager)
>
> Because I don't respond to territorial markings … it suddenly doesn't work anymore. … Then they listen too. (Female TO manager)
>
> It doesn't have to be exactly equal, but certain behaviors are just neutralized. (Male shareholder)

The men we surveyed noted similar patterns: If several or "competent' women are in the team, "the man becomes more of a gentleman, right?" (Male transfer manager). While men talk about "cockfights that happen even in all-male teams" (male shareholder), most of the female managers we surveyed describe these situations as "astonishing". Nonetheless, typically male behavior still has advantages—or other behavior has disadvantages, as the following quote exemplifies:

> If you're in this environment now, [reserved behavior] is a disadvantage. Because no one sees you. That behavior and its external effect is a sharp difference between women and men. (Female transfer manager)

Mostly older male decision-makers refuse to think about a gender dimension in their work in the future. According to a few statements made by such men, that also applies in a gender-nonspecific way to all leading managers.

> When I think about my selection committee now and these generally somewhat older man of course have no desire to consider it. And the women who managed to reach certain positions, they also don't want to push the issue. You just can't say that gender is a women's issue. It's not like that. (Male shareholder)

That is not the case among our interviewees. The (male) managers cite multiple reasons why the gender dimension has so far not been discussed: Lack of time, lack of resources to implement new ideas, the novelty of thinking about gender (and its negative connotations), minimal acceptance among male and female colleagues, and not least of all a low chance of success. In addition, the men we interviewed were the only ones who appeared to be disinterested:

> I am very passionate about KTT. I really found myself there. And it's almost charity work, what I do. But this gender thing … I have never really concerned myself with that. To some degree maybe because I already to live in a gender-balanced world. (Male transfer manager)

Younger men in our sample (along with successful women) particularly distanced themselves from gender stereotypes. In contrast to the older men, they do not perceive gender as a decisive factor:

> I think – so I don't know how women experience it, but for me it is not like there are [pause] women and men. Like that. (Male scientist)
>
> And so it's actually not a factor at all whether man or woman. (Male shareholder)

While women in KTT ascribe different characteristics to themselves and others according to their position, the negotiation process among male participants differs with the age of the participant. Younger men refer to stereotypes much less. The few men we surveyed who lead mixed-gender teams and are more mindful of the "type of person" than the gender also expressed greater openness. They were the only ones who defined gender as a possible delimitation of different forms of socialization and everyday realities (for example, differences in typical daily routines and in acquired "tacit knowledge"; Nonaka 1991). These are people who explicitly desire a diversity of perspectives and are very open to greater involvement of the gender dimension in the future in the form of qualitative assessment criteria, stronger product orientation to female customers, or more participation by women. Also noteworthy was the fact that these performance-minded men were able to define selection criteria and processes relatively clearly (according to those who were asked about this) and bring more women into their team.

Conclusions

The objective of the present investigation was to determine the extent to which contemporary male and female knowledge carriers and decision-makers in KTT have integrated the gender dimension. The research focused on transfer organizations and transfer-oriented research departments at the interfaces that characterize KTT culture. Based on a KTT model that we developed ourselves and a current definition of the gender dimension, comprehensive research and 22 key informant interviews have shown that the gender dimension has not yet been adequately integrated although the odds of a cultural shift in KTT are good.

The low degree of gender-dimension integration in all KTT procedural steps has been demonstrated and important variables and structures have been revealed through an analysis and summary of current studies and statistics. Within that framework, the qualitative survey provided valuable overriding insights into the reasons and background for gender blindness beyond the individual level. In the process, it became apparent that stereotyping greatly inhibits successful integration of the gender dimension because traditional ideas about gender ascribe less technical competence to women and support one-dimensional attribution of gender-specific needs and abilities. While stereotyping of that kind pervades statements made by men as well as by women, a closer look reveals noticeable differences: While age appears to be a deciding factor for the degree of stereotyping by men, for women it is the hierarchical level. The qualitative survey therefore showed that older men and women at the sub-management level reproduced traditional stereotypes with noticeable frequency and showed less drive or power to change or implement comprehensive gender-dimension integration. By contrast, in our sample, younger men and women in leadership positions dissociated themselves from gender stereotypes. KTT's work-history openness and the possibility of profitably applying traditional female characteristics (Achatz et al. 2009), however, are not as yet expressed in greater career prospects. The so-called high performance culture (Sonnert and Holton 1995), the most common working culture in German research organizations, also standardizes career opportunities in KTT. Our research, therefore, also explains why female representation in KTT decreases with each process level and in managerial positions.

In aggregate, the results can be regarded as a sign of a lack of qualitative integration given that KTT decision-making structures, cultures, and formal as well as informal forms of work and interpretive frames are implicitly oriented to male models (Matthies 2001; Acker 1990; Faulkner 2006).

The existence of various interpretive concepts (K1, K2) appears to be a double-edged sword for gender-dimension integration into KTT: On one hand, is shows the persistence of stereotypes on the individual and organizational levels despite a putative equality of opportunity. On the other hand, it can be seen as an opportunity: The growing number of women in management positions and younger men (both of which are more open to complete qualitative gender-dimension integration) implies a possible impending cultural shift. This is supported not least of all by the altered self-assessment of young men who include characteristics with female-connotative characteristics and views.

The present investigation has helped to close a gap in the existing research but it has opened new ones as well, particularly in the research on the international comparability of the results. Moreover, criteria for testing the integration of the qualitative components of the gender dimension still need to be developed. In its high degree of ambivalence between simultaneous gender concepts and its key position between economy and science, KTT can be regarded as a model and testing ground for additional parts of the full system.

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3

Women's Role in Biotechnology Research: The Case of Mexico

Humberto Merritt and Maria Pilar M. Perez-Hernandez

Introduction

Although the share of women in science and technology education has been growing in recent years, available statistics suggest that female participation in the labor market is still low and varies considerably between countries, age groups, areas of work and educational background (OECD 2006; UNESCO 2007). Participation rates seem to be higher in Scandinavian countries, North America, and a few Western European nations but lower in Asian countries. In the Organization for Economic Co-operation and Development (OECD) region the

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population of female researchers has steadily increased in the last 20 years, with women now accounting for 25–35% of the R&D personnel in most OECD countries (OECD 2014).

As regards the field of knowledge, women scientists concentrate in a handful of areas. In the case of the United States, 81% of female researchers are found in only three disciplines—psychology, social sciences, and life sciences (largely in biology), with very low numbers in the so-called STEM careers (i.e., science, technology, engineering, and mathematics) (Ecklund et al. 2012; OECD 2014). Moreover, women tend to concentrate in lower level academic positions, with just over one-third of the American university faculty being women, whereas in Europe, women make up <20% of senior academic staff in the majority of countries (Smith-Doerr 2004; Stephan and El-Ganainy 2007; OECD 2014). On the other hand, over the years there has been a growing pressure in scientific institutions to encourage faculty to commercialize the products that result from their research. In this respect, Rosser (2014) reports on the rising tendency among American universities to include patents, along with peer-reviewed publications, in tenure and promotion decisions; and clearly, women scientists have not been immune to these pressures too.

In many respects, female researchers are becoming more and more interested in reaping the benefits from the commercialization of their inventions, but balancing professional interests and personal duties is commonly a hard choice for them (Ecklund et al. 2012). For example, Polkowska (2013) has pointed out that female scientists, who are also nurturing entrepreneurial ambitions, generally face strong cultural barriers when they seek to successfully start and run a business. And these obstacles are more or less common everywhere in spite of the various advances made in reducing the gender gap. In the case of developing nations, women scientists also need to deal with unfair economic restrictions, mostly associated with lower salaries and poorer working conditions. As, for example, financial institutions in Mexico do not typically give credit to women on their own, forcing them to require husbands or fathers to co-sign loan applications (Kelley et al. 2013: 23).

In this context, the aim of this chapter is to investigate how scientific entrepreneurship is driven by gender factors in Mexico, specifically at the National School of Biological Sciences (Escuela Nacional de Ciencias Biológicas—ENCB) of the National Polytechnic Institute (Instituto Politécnico Nacional—IPN). We are particularly interested in analyzing what role female scientists play in pushing the knowledge frontier in the life sciences and how hard is for them to commercialize their discoveries. To this end, the chapter is structured in eight sections, including the introduction and conclusions. The following section deals with the commercialization of scientific works since a gender lens. Sections three and four discuss the case of Mexico. First, the situation of female scientists in Mexico wanting to become entrepreneurs is described, and then the institutional framework for scientific entrepreneurship in the country is presented. The fifth and sixth sections discuss the case of the National School of Biological Sciences, which is the research unit of this paper. First, a general description of the institutional setting of ENCB is done and then (in the sixth section) empirical findings are reported. The seventh section deals with the issues concerning the commercialization of scientific discoveries from female researchers at ENCB. Finally, the paper presents the main conclusions.

The Gender Dimension of Scientific Entrepreneurship

In the last 10 years the scholarly interest in academic entrepreneurship, and its relation to the commercialization of university research has focused on the role that female researchers play in forming science-based businesses. It is not surprising, therefore, that a growing body of literature is being constructed on women's academic entrepreneurship (Murray 2004; Rosa and Dawson 2006; Dahlstrand and Politis 2013; Polkowska 2013; Martin et al. 2015).

But prior to the research in this topic there was the study of the reasons behind the relative scarcity of female scientists. To a large extent, analyses carried out in the social sciences arena prompted the debate around the question "why are women so underrepresented in the sciences?" with several interesting reflections put forward. One of the most popular is the so-called "leaky pipeline" metaphor, which describes the fact that women are underrepresented in STEM careers because the educational pipeline leaks students at various stages (Blickenstaff 2005). Another popular explanation deals with the unseen, yet impassable, barrier that keeps women (as well as other minorities) from rising to the upper rungs of the scientific ladder, regardless of their qualifications or achievements (Cotter et al. 2001).

Although former studies paved the way to tackle the analysis of the relatively few cases of women entrepreneurs with a scientific background, two main issues remain. First, the cultural barriers that women need to overcome in order to become successful scientists and the issues regarding the risks and uncertainty that they face during the commercialization of their scientific discoveries. By considering the two main theoretical approaches mentioned above, one can assume that the leaky pipeline metaphor should help us explain the phenomenon given the fact that the number of women scientists that become entrepreneurs is a smaller subset of pure scientists but the reality is more complex because the population of women entrepreneurs is vastly understudied, as Brush (2008) argues.

According to Brush, the lack of empirical analyses on businesswomen is due to long-lasting stereotypes such as women are less qualified and less capable than men, and so more likely to start "hobby-type businesses." As a result, the few studies that address this issue tend to focus primarily on economic dimensions [e.g., decision-making, labor, capital, and pursuit of profit with less attention to the social and cultural dimensions of the problem (Brush 2008: 616)]. Yet, available evidence suggests that, in general, women are more likely to be present in service and retailing, even though there have been dramatic increases of women founding and growing technology-based firms (Dahlstrand and Politis 2013; Kelley et al. 2013, Martin et al. 2015). Besides, according to several studies, life sciences seem to be the field of knowledge that female academic entrepreneurs prefer in order to establish their businesses (Ding et al. 2006; Rosa and Dawson 2006; Murray and Graham 2007; Fältholm et al. 2010).

As regards the non-economic barriers that women generally face, Fiona Murray (2004) find that the social capital of academic scientists is critical to firms because it can be transformed into scientific networks that embed the firm in the scientific community through a variety of mechanisms. In this respect, several studies have highlighted the crucial role that social networks play in fostering commercial activity among faculty. The gender literature on entrepreneurship has found that men and women are embedded in different social networks and suggests that network differences lead to divergent economic consequences, see, for example, Stephan and El-Ganainy (2007), Brush (2008) and Martin et al. (2015). According to Brush (2008), social networks are central to resource acquisition, suggesting that female entrepreneurs engage in weaker networking ties than their male counterparts.

Given that central network positions and the ability to connect effectively with others in the organization provide access to knowledge and improve the ability to innovate, the analysis of these conditions may help explain the intensity and richness of interpersonal networks in which collaborative research takes place. As pointed out by Ranga and Etzkowitz (2010), innovation studies are shifting their focus from product and process innovations towards the analysis of services in both the public and private sectors. So, the contextual explanation of the entrepreneurial puzzle is that women have historically been under-represented in the types of positions from which the faculty typically launch entrepreneurial activity. Not only are they less likely to be employed at top universities but also, in a related manner, they are less likely to have the financial support that leads to success in academe.

In this respect, Stephan and El-Ganainy (2007) have proposed two sets of factors that seem to explain the lack of female academic entrepreneurs. They distinguish supply-side elements from demand-side factors, as the following two tables summarize (Tables 3.1, 3.2).

Being both supply-side and demand-side factors as important in determining the propensity of female scientists to venturing into commercial research as personal traits, the study of social networks has become a central topic in this phenomenon. Although female scientists tend to lack strong commercial networks, as compared to their male colleagues, they are nonetheless equally productive in scientific terms. For example, Sue Rosser observes that women are equally as likely as men to become involved in patenting, although they still do not patent as frequently as men. She argues, however, that there is a higher citation

Table 3.1 Supply-side factors inhibiting female scientists to become entrepreneurs

Factor	Reasoning
Risk-aversion	Women are generally more risk averse than men with regard to financial decisions
Dislike of competition	Women dislike competition more than men
Lack of interest in selling of science	Women may be less predisposed to "sell" the science that they are doing
Lower tendency towards self-promotion (the importance of asking)	Women are less likely to ask than are men and, to some extent, women are less likely to seek out opportunities than are men
Research ambitions (type of research)	Gender differences exist in research focus, with women choosing foci with less commercial possibilities than men
Entrepreneurial profile (characteristics venture capitalists like)	Women are less likely than men to have high productivity and appointments at Scientific Advisory Boards
Personal commitments (tradeoffs)	Women traditionally have more responsibilities outside the workplace than do men
Location (the importance of geography)	Geography provides less of an advantage to women today than in the past
Collaboration affinity (exposure to commercial activity)	To the extent that friendships are gender-based, women have a lower probability of associating with (male) colleagues who are patenting, commercializing or having contact with industry

Source Authors' elaboration based on Stephan and El-Ganainy (2007)

count for women's patents because they hold fewer patents of "dubious merit" compared to men (Rosser 2014: 115).

As regards the relationship between men and women in academic entrepreneurial endeavors, Rosa and Dawson (2006) observe that women are prone to be part of teams involving senior male colleagues although they also face gender-specific obstacles such as the conflict between work and home life. On their part, Murray and Graham (2007) argue that exclusion and the limited activation of women's scientific networks for commercial opportunities mean that women are less able to resolve the ambiguities felt by all scientists in the early days of

Table 3.2 Demand-side factors inhibiting female scientists to become entrepreneurs

Factor	Reasoning
Role of networks	Women are at a disadvantage compared to men to receive referrals from venture capitalists. In addition, women faculty train fewer graduate students and post-docs on average than do men. Finally, membership in scientific advisory boards was overwhelmingly male
Venture capitalists	Because venture capitalists are mostly male, they have a higher comfort level with men than with women
Women aren't asked	Because of gender bias, women are less likely to be called for commercial engagements
Gender discounting	The accomplishments of women are viewed differently than those of men
The "academic club" is still a "boy's club"	Academies, which were once almost exclusively male, had been opened, partly to women through affirmative action

Source Authors' elaboration based on Stephan and El-Ganainy (2007)

commercial science. Unfortunately, both of these problems are particularly acute in Mexico, as we shall see below.

In searching for explanations to what factors determine business venturing in the academic world, Louis et al. (1989) argue that individual characteristics and attitudes (such as achievement motivation) seem to be the main source of academic entrepreneurship. In particular, they point out that more established scientists may be less motivated to become entrepreneurs because of the influence of traditional academic incentives such as tenure and disciplinary awards, whereas women, who have tended to be less scientifically productive, may also be less likely to be entrepreneurial (Louis et al. 1989: 111). These authors distinguish five types of academic entrepreneurship: (1) engaging in large-scale science (externally funded research), (2) earning supplemental income, (3) gaining industry support for university research, (4) obtaining patents or generating trade secrets, and (5) commercialization-forming or holding equity in private companies based on a faculty member's own research. Because of its utility, in this paper, we take advantage of the conceptual framework proposed by Louis and colleagues to analyze the case of Mexican female scientists wanting to commercialize their inventions.

Women Scientists and Entrepreneurs in Mexico

To begin with, the participation of Mexican women in science and technology has historically been very sporadic. Although their first engagement in higher education is reported to have occurred in the late nineteenth and early twentieth century, the true rise of women's enrollment in universities began in 1960 thanks to three institutional changes. (1) a strong increase in the public sector education budget, (2) an official mandate to offer universal access for all children to elementary school, and (3) a marked shift in urbanization (Blazquez and Flores 2005).

Even though the number of female students enrolled in tertiary education has been growing since 2000, the "leaky pipeline" metaphor seems to have some rationale in the case of Mexico because the proportion of graduate women in 2010 was roughly <16% of all female Mexican citizens aged 15 and older, as Table 3.3 shows.

This situation means that the availability of qualified female human resources in Mexico, as measured through the proportion of women with tertiary education, is still limited because only one in six female citizens aged 15 and older exhibits a competent level of education as to understand, analyze, and solve complex professional requirements. As a consequence, most Mexican women face huge challenges for accessing better paid jobs, especially those related to high-technology sectors.

Table 3.3 Mexican population aged 15 and older with tertiary education, 2000–2010 (million people)

Year	Mexicans aged 15 and older			Mexicans with tertiary education		
	Total	Women	(as %)	Total	Women	(as %)
2000	62842.6	32798.8	52.1	6868.6	3083.1	44.8
2005	68802.6	36019.8	52.3	9318.3	4466.4	47.9
2010	78423.2	40767.0	51.9	12958.8	6481.9	50.0

Source Authors' elaboration based on INEGI, National Census on Population, available at the URL http://bit.ly/1Fb4CbI. [Retrieved on April 20, 2015]

On the other hand, while the ratio between men and women in higher education is almost 50–50, and in some areas the presence of women is even higher—as for example in life sciences—women account for barely 30% of all professionals devoted to scientific research (OECD 2009). According to the OECD, this is largely due to structural conditions that limit the access of women to higher positions of power that have been predominantly taken by men. Yet, women's participation in science passed from the level of 24.3% in 1990 to 35.3% in 2004, mainly propelled by the growth of university female students (Blazquez and Flores 2005). From 1969 to 1985, as higher education enrollment expanded more than fourfold, the rate of growth for women was almost three times that of men, with women constituting 44 % of the undergraduate population in 1990.

Although available data comprehend all disciplines, a good indicator of the historically growing participation of women in graduate education is the increase from 23% (in 1971) to 33% (in 1989) of all scholarships awarded to women by CONACyT, the Mexican research funding agency, as reported by the OECD (1994) and, according to this international organization, the number of female university

graduates in employment as a percentage of the population of university graduates aged 25–64 in 2012 was around 72% which is a relatively high figure but still lower than that of their male counterparts (OECD 2014: 243).

As regards the women's participation in research and development, it can be weighted through their membership to the Mexican National System of Researchers (SNI). It is worth mentioning that the SNI system was created in 1984 by the Secretariat of Public Education (SEP) in order to enhance the quality and productivity of Mexican scientists. It gives pecuniary compensation, as a complement of salary, to the most productive researchers in the country. Affiliated researchers are periodically evaluated by their peers in order to assess whether or not the compensation shall continue (OECD 2009). Therefore, the affiliation to the SNI system can be regarded as a measure of the Mexican scientists' level of academic productivity. Although women only account for nearly a third of the system, their numbers have been steadily growing from 2010 onwards, as Table 3.4, next, shows.

Table 3.4 SNI membership by gender, 2010–2013

Year	Total SNI members	Women	As % of total
2010	16598	5519	33.3
2011	17639	5907	33.5
2012	18555	6220	33.5
2013	19747	6867	34.8

Source Authors' calculations based on National Council for Science and Technology (CONACyT), S&T General Report, various years, Available at the URL http://bit.ly/1Lrq0eD. [Retrieved on July 27, 2015]

A 2005 gender analysis of two of the country's leading scientific institutions shows that women accounted for 26% of the researchers in the schools and centers of the National Polytechnic Institute (IPN) and 30% of the scientists at the Autonomous National University of Mexico (UNAM), but they accounted for only 2% of Mexico's scientific managers and policy makers (Blazquez and Flores 2005). No wonder, then, that women very seldom are found in high-level scientific posts in Mexico. Even when women attain such positions, a man is still usually in charge and handles external relations while the woman manages the internal aspects of the organization (Hualde 2012). The lack of women in higher organizational levels could be related to the fact that they are typically not interested in engaging in the politicking required to achieve senior status. Yet, many women eschewed this informal aspect of scientific advancement because of the constraints on their time imposed by family obligations (Etzkowitz et al. 2000: 208).

Another factor that shapes the route of female scientists in Mexico is the implicit discrimination that plays a role in the composition of scientific agencies that are mainly explained by their ancillary political and organizational aspects. For a woman to be taken seriously as a potential scientist she has to demonstrate a greater knowledge and research ability than their male counterparts but, in doing so, she has to exert an extreme concentration on securing her knowledge base, which in turn has an impact upon her options for academic productivity (Hualde 2012). This type of gender-related academic pressure generally provokes that Mexican female scientists typically develop their research findings more fully than men before publishing; a phenomenon that has also been noted in other places, such as the United States and

Europe (Ecklund et al. 2012; Maliniak et al. 2013). The situation of Mexican female scientists should be addressed in the context of the field of life sciences, and particularly in the case of the National School of Biological Sciences (ENCB), the country's leading science and technology institution in biology education. The following section deals with this issue.

The Institutional Framework for Scientific Entrepreneurship in Mexico

After World War II and up to the mid-1970s, Mexican industrial development was defined by the so-called import-substitution model. This resulted in an inward-looking strategy that favored protection and regulation over open markets with foreign investments lacking technology transfers. As a result of protection and over regulation, industry was static, inefficient and technologically obsolete. So, industry-university links were virtually non-existent (Merritt 2008). By the mid-1980s, public policy began to follow an open and deregulated economic model. In 1987, the Mexican regime unilaterally accelerated the opening of the economy. In 1990, Mexico initiated negotiations for a comprehensive free trade agreement with the United States, and on 7 October 1993 Mexico, Canada and the United States signed the North American Free Trade Agreement (NAFTA), which became effective on 1 January 1994 (OECD 1994).

In the last two decades, a number of programs to support business R&D and innovation have been developed and implemented by CONACyT. Although these initiatives have generally had a positive effect on enterprises' investment in R&D and innovation-related activities, they have relied on public funds to support their activities. Indeed, between 2002 and 2005 the share of direct government financing of total business R&D investment increased from 1.5 to 5.7% (OECD 2009: 176). This situation is somehow anomalous given the incentives created by NAFTA. Yet, most domestic firms still lack R&D facilities, have need of highly trained personnel and avoid devoting financial resources to basic and applied research (Merritt 2015).

Table 3.5 Patents granted in Mexico, 2004–2013

Year	Total patents granted	Patents granted to nationals	As % of total
2004	6838	162	2.37
2005	8098	131	1.62
2006	9632	132	1.37
2007	9957	199	2.00
2008	10440	197	1.89
2009	9629	213	2.21
2010	9399	213	2.27
2011	11485	229	1.99
2012	12330	245	1.99
2013	10343	302	2.72

Note Nationals are lone inventors, universities or enterprises located in Mexico
Source Authors' elaboration based on CONACyT, 2014, p. 74

As regards the incentives devised to encourage domestic patenting, the Mexican government reformed the law to protect industrial property rights on 28 June 1991. Although the spirit of the reform was to reinforce the institutional setting for industrial innovation, the number of patents held by nationals has remained extremely low over the last ten years, as Table 3.5 shows.

According to the OECD, as technology adaptation and incremental innovation tend to require little recourse to patent protection, it is quite possible that continuing low levels of patenting among Mexican firms might be expected in the medium term (OECD 2009: 104). These results nonetheless suggest that in Mexico, contrary to what advocates of strengthening industrial property laws have since long proclaimed (see, for example, OECD, 1994, p. 121): (1) the introduction of stronger legal incentives to protect the industrial property has not helped domestic firms, (2) linkages between industry and universities remain as weak as ever, and (3) technology transfer to industrial firms has not yet been the most efficient and low-cost method of technological modernization of nationals firms.

On the other hand, the existing set of incentives in the Mexican S&T system has encouraged individual researchers to patent their inventions. As mentioned above, since the SNI membership gives an additional pecuniary compensation to the most productive researchers in the country, it is hardly surprising then that scientists at higher education institutions, especially those involved in STEM fields, tend to use patent claims as a proof of their productivity, as we shall see below.

The National School of Biological Sciences (Encb)

One the second oldest. In 2009, the School celebrated its 75th anniversary. Over the of the most important loci of scientific entrepreneurial activity in Mexico is placed at the National School of Biological Sciences (ENCB) of the National Polytechnic Institute of Mexico (IPN). The ENCB is one of the 83 colleges that form the IPN and years, the institution has become an important pillar of the life sciences at national and international levels thanks to its outstanding research and teaching records[1].

The ENCB spun off from the National Autonomous University of Mexico (UNAM) in 1934, when several professors got fed up of the conservative intelligentsia that dominated that institution. Between 1938 and 1940 several prestigious researchers, who were fleeing from the Spanish civil war, joined the ENCB and thus reinforced its academic structure and capabilities. Nowadays the ENCB offers five baccalaureate degrees, and several specialty and postgraduate courses (i.e., master and doctoral degrees in sciences). ENCB's researchers are internationally acknowledged because of their scientific prestige. They teach and do research on food sciences, biomedicine and molecular immunology, and biotechnology and chemical sciences. ENCB has obtained several important awards and academic certifications, including the prestigious CONACyT's "Postgraduate Program of Excellence" recognition[2]. Over the years the number of students enrolled at the baccalaureate level has been growing, passing from 2924 in 2003 to 3391 in 2010, whereas the number of postgraduate students reached a first peak in 2006, and then another one in 2008 to remain stable from that year on (Villa 2009: 22).

As regards the gender issue, the latest available data show that in 2013 2192 women students were enrolled at the baccalaureate level, out of 3708 persons, which is 59.1% of the total enrollment. At the postgraduate level, 344 women were registered in the same year, which accounted for 60.5% of the total enrollment at that level (569 students). These figures confirm previous empirical findings claiming that women generally display a hefty majority in life sciences (Smith-Doerr 2004; Ecklund et al. 2012). In relation to its staff, the ENCB is one of the IPN's faculties with the greatest proportion of researchers with a Ph.D. degree.

In relation to the role that women scientists play at the ENCB, it is worth noting that the institution is widely recognized as an important hub of highly qualified female human resources in life sciences not only in Mexico but also in Latin America. In this respect, the National Polytechnic Institute gathers yearly statistics of all of its researchers enrolled in the Mexican National System of Researchers (SNI). According to the 2013 data, the number of SNI researchers affiliated to the ENCB was 145, prompting the school as the single most important concentration of highly qualified human resources for the 83 schools that form the IPN. Not only are these figures respectable in terms of the sheer number of researchers involved but also in terms of their gender composition. That is, women accounted for by 54.5% of all SNI members at ENCB in that year (see IPN, 2015, p. 107).

In order to put these figures into context, Table 3.6 displays the proportion of female SNI members from the ENCB measured through the different categories that exist in the Mexican National System of Researchers.

Keeping an adequate rate of scientific productivity is of chief importance for researchers at ENCB since the IPN has been aligning its

Table 3.6 SNI membership at ENCB by gender, 2013

SNI membership statistics	Members	As % of previous total
Total SNI members	19745	..
Total women SNI members	6835	34.6
IPN total SNI members	952	..
IPN total women SNI members	284	29.8
ENCB total SNI members	145	..
ENCB total women SNI members	79	54.5

Source Authors' calculations based on CONACyT, SNI's historical statistics. Available at http://bit.ly/1Jq8Dac. [Retrieved on July 29, 2015] internal rules to meet CONACyT's requirements for granting membership to the SNI[3]. Therefore, becoming a member of the SNI system means for a researcher at the ENCB to receive an institutional recognition to the quality of his/her research. Moreover, as part of their contractual duties, researchers affiliated to the ENCB are asked to teach postgraduate students and that includes supervising the concomitant research theses. In this respect, several of these theses end tackling practical problems in the food industry, as well as those pertaining to the health sector. These conditions have encouraged the creation of research department within the ENCB with some of them also involved in the commercialization of their scientific work. One of the most productive is devoted to the research of the human immune system. In this group participate Mayra Perez-Tapia and Iris Estrada-Garcia, who are two leading female scientists at the ENCB, as we shall see below.

Due to the importance, and market potential, of their research work, several ENCB scientists have since long sought to protect their discoveries. However, their actions have not always been easy or swift to instrument because institutional factors have somehow hampered the registration process of intellectual property. For example, before 1999, when a more flexible legislation in Science and Technology was enacted, most Mexican universities, including the IPN, were adamant in reclaiming the intellectual property of all discoveries developed into their facilities (OECD 2009). Because public resources were involved in the discovery and development process, universities argued that they were entitled to claim the largest part of the potential royalties. So, as the 1999 S&T law came into effect, Mexican researchers were now allowed to retain a bigger share of the royalties. As a consequence, most scientists felt encouraged to seek for patents, and the number of patents granted to researchers began to grow from 2000 onwards. In the case of the ENCB, several researchers harnessed the institutional shift and started to patent as a logical path towards the commercialization of their discoveries. It is worth noting that research groups are normally led by senior researchers, with many of them overwhelmingly led by male scientists. Yet, the proportion of women leading these groups has been growing and some of them are now widely acknowledged, as we shall see later in the paper.

In order to explore the ways researchers at the ENCB seek to commercialize their inventions, we take advantage of the conceptual framework proposed by Louis, Blumenthal, Gluck and Stoto (1989). This model has identified five types of academic entrepreneurship: (1) engaging in large-scale science (externally funded research), (2) earning supplemental income, (3) gaining industry support for university research, (4) obtaining patents or generating trade secrets, and (5) commercialization-forming or holding equity in private companies based on a faculty member's own research.

Given that female researchers at the ENCB are playing an increasingly important role in the life sciences in Mexico, the following section reports their productivity as measured by the number of international patents granted to them.

Patenting by Women Scientists at Encb

As mentioned above, ENCB researchers have harnessed the more amicable institutional conditions regarding the protection of their intellectual work and have increasingly applied for patent protection both nationally and internationally. In order to investigate the patenting activity of ENCB female scientists, we decided to use the Espacenet patent search database (http://www.espacenet.com), which offers several criteria to retrieve patent information from a worldwide collection of published applications from 90+ countries. By entering the title "National Polytechnic Institute" and the country code [MX] in the Applicant's Name field, we were able to retrieve 212 records covering the years 1996–2014. From the 212 records retrieved, we selected only those that described patents actually granted to scientists at the ENCB. By cross-checking the institutional affiliation of the patentee with the ENCB staff database, we were able to extract 92 records fulfilling the latter criterion. Empirical findings are reported next.

The analysis of the 92 records retrieved from the Espacenet patent search database shows a growing rate to patent from scientists at the ENCB, especially in the last seven years. Figure. 3.1 shows the evolution of patents granted to scientists (men and women) at the ENCB from 1997 to 2014.

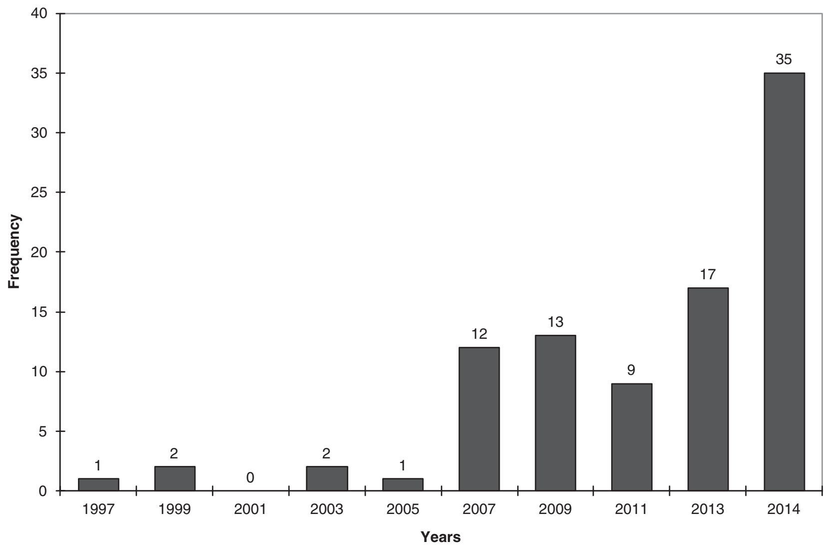

Fig. 3.1 International patents granted to ENCB researchers from 1997 to 2014. *Source* Authors' elaboration, based on data retrieved from the Espacenet patent database. Available at http://www.espacenet.com [Retrieved on June 20, 2015]

Country data analysis shows that 80 out of the 92 patents retrieved were granted in Mexico (86%), 9 (9.7%) were granted on a worldwide basis under the Patent Co-operation Treaty (PCT), and the 3 remaining patents (4.3%) were granted in the United States. These results suggest that researchers at ENCB have an overwhelming preference for patenting in Mexico[4].

As regards the number of inventors involved in the patent process, available figures show that the average number of applicants was 3.02, which suggest the existence of incipient team collaboration at the ENCB. Table 3.7 shows the distribution of applicants for each patent.

As displayed in Table 3.7, almost two-thirds of patents granted to the ENCB researchers involved up to three inventors, with 23 patents (25% of the total) granted to lone inventors, of which 8 (34.8%) were granted to women and the rest (15, or 65.2%) to male inventors.

In relation to the gender issue, a detailed revision of the number and sex of applicants allowed us to determine the structure of collaboration. Table 3.8 shows the number and gender of patent applicants in the sample.

Table 3.7 Number of applicants in patents awarded to ENCB Staff, 1997–2014

Number of inventors	Number of patents	As % of total	Cumulative percentage
1	23	25.0	25.0
2	12	13.0	38.0
3	21	22.8	60.9
4	21	22.8	83.7
5	9	9.8	93.5
6	5	5.4	98.9
9	1	1.1	100.0
Total	92	100	

Source Authors' elaboration, based on data retrieved from the Espacenet patent database. Available at http://www.espacenet.com. [Retrieved on June 20, 2015]

Table 3.8 Number and gender of applicants in patents awarded to ENCB Staff, 1997–2014

Number of female inventors	Total number of inventors							Number of patents	As % of total
	1	2	3	4	5	6	9		
None	15	6	8	8	1	2	1	41	44.6
1	8	4	7	8	4	3	–	34	37.0
2	–	2	6	4	2	–	–	14	15.2
3	–	–	–	1	1	–	–	2	2.2
5	–	–	–	–	1	–	–	1	1.1
Number of patents	23	12	21	21	9	5	1	92	100.0

Source Authors' elaboration, based on data retrieved from the Espacenet patent database. Available at http://www.espacenet.com. [Retrieved on June 20, 2015]

As shown above, 41 patents (44.6%) were granted with no women participating in the process, and the rest (51, or 55.4%) with a varied degree of female participation. When considering the gender of the first inventor, some interesting findings emerge. Data analysis suggests that the greater the number of female inventors, the lower the number of patents granted for them. Moreover, when the first inventor is a man, only one or two women tend to collaborate even though men do collaborate in almost half of the patents involving female inventors. However, most female researchers tend to participate in patent applications when their male counterparts are the majority.

Given the odd pattern that emerges for these results, we should elaborate a further reflection on this. Firstly, although this pattern may suggest that women scientists at the ENCB exhibit a sort of research dependence on their male colleagues, the entrenched male-dominated institutional milieu, which normally prevails in Mexico, might be playing a role too. That is, men traditionally lead most academic departments (including the IPN), so women are accustomed to see this structure as "the rule" and thus rarely prompted to object it. Secondly, it is just until relatively recently that prominent women, such as Drs. Baeza-Ramírez, Ortiz-Moreno, Dorantes-Álvarez, and Ramón-Gallegos and Pérez-Tapia, started to make strides in scientific research at the ENCB that they started to become acknowledged as effective as their male colleagues, and thus being able to form and lead their own research groups. Thirdly, in Mexico most institutional support (and the financial incentives that emerge from it) is plagued with bureaucratic restrictions and rules that ask for additional time and effort to learn and master, so men are more likely to spend personal time in lobbying for support and resources than women, especially if they rear children or need to take care of their families[5].

In order to grasp a better picture of this, Table 3.9 displays the structure of gender collaborations in patents granted to ENCB staff in the sample.

As shown above, 30 out of 92 patents granted to ENCB researchers were filled by women as first inventors (i.e., 32.6%). Moreover, as total inventors grow, the number of patents with a woman as first inventor declines. It appears that female scientists at the ENCB might be leading smaller research groups than their male counterparts. Although the analysis carried out here does not allow us to gage the quality of the patents granted, one should then observe the effects of these phenomena on total performance, which is clearly lower for female scientists, as the proportion of female involved in all patents granted to ENCB from 1997 to 2014 was 26.3%. There is an outlier case, though. It is a patent granted in 2014 to five female inventors from the ENCB. The patent covers the development of a monoclonal antibody directed against a virus present in the membrane of cells infected with human papilloma. It was registered under the PCT number WO2014051412 (A1).

Table 3.9 Number of patents granted and number of inventors involved, by gender, 1997–2014

Number of patents granted to...		...Of which a woman was the first inventor	As % of total patents granted	Number of women involved (in total)	As % of total inventors
One inventor	23	8	34.8	8	34.8
Two inventors	12	4	33.3	8s	33.3
Three inventors	21	6	28.6	19	30.2
Four inventors	21	7	33.3	19	22.6
Five inventors	9	5	55.6	16	35.6
Six inventors	5	0	0.0	3	10.0
Nine inventors	1	0	0.0	0	–
TOTALS	92	30	32.6	73	26.3

Notes Numbers of inventors are reported as aggregated without weighting figures
Source Authors' elaboration, based on data retrieved from the Espacenet patent database. Available at http://www.espacenet.com. [Retrieved on June 20, 2015]

The assignees are Eva Ramón-Gallegos, Yolanda Medina-Flores, Araceli M. Zavala-Carvallo, Irma De León-Rodríguez and Sharlly R. Juárez-Palafox. It is noteworthy that this patent signals at the research field in which this important group of ENCB female scientists have specialized: immunology. The following section deals with the main obstacles women scientists at the ENCB tend to face when trying to commercialize their intellectual property.

The Commercialization of Inventions by Women Scientists at Encb

The commercialization of scientific discoveries in Mexico is still in its infancy. Although the government has since long pursued an active policy for promoting technology transfer from academy to industry, its results are seldom tangible, let alone effective (Merritt 2008). One reason for this detachment is the secular lack of interest from business firms to engage in collaborative research with academy (Merritt 2015). This separation has produced a sort of two independent institutional trajectories. On the part of enterprises, their technological needs are normally covered through the imports of industrial knowledge embedded in new machinery and turn-key plants. A situation that explains the very low number of patents granted to nationals in Mexico, as depicted in Table 3.5, above. On the part of universities, academics have mostly pursued their own research interests, which generally go through the fundamental (basic) research spectrum. As a consequence, the exploration of market opportunities for university knowledge is generally weak and normally avoided because of the risk and uncertainty involved.

In the case of the National Polytechnic Institute, Perez-Hernandez et al. (2011) report an institutional shift in 1986 in order to encourage scientists to commercialize their research. Over the years, the IPN's market orientation has got stronger with the creation of a technology-based business incubator in 2001. This unit received a research grant from CONACyT to encourage commercial initiatives to spin-off business ventures derived from research projects. One of the most successful initiatives so far has been the creation of a commercial office to profit from immunology research at the ENCB. This venture has registered the Transferon brand, which is a vaccine produced from synthesizing human leucocytes for treating allergic diseases. Female scientists, such as Drs. Sonia Mayra Pérez-Tapia and Iris Estrada-Garcia, have played a crucial role in this venture[6].

In spite of its growing market-friendly approach, the IPN still face several institutional weaknesses. For instance, non-market relationships, such as those embodied in industry standard-setting bodies, professional and trade associations, and inter-institutional cooperation also influence the process of technology commercialization. On the other hand, these attempts have been severely hampered because internal and external parties have sought to enforce IPN' adherence to its historic commitment to create and sustain an intellectual commons for the benefit of the Mexican society at large. In the case of direct commercial involvement by ENCB women scientists, the emerging characteristics of some successful inventions have provided them with the management skills that permit an easier entry into the private sector. However, the formation of private firms devised at profiting from their own research has not yet been as continuous as expected because of red tape and lack of effective institutional encouragement. To a large extent, this form of entrepreneurship might be the most attainable in the short-run since it involves the potential use of ENCB facilities and graduate students in order to cut start-up costs, yet, the lack of institutional flexibility to sign contractual permissions discourages female scientists to stay researching at the ENCB and become entrepreneurs.

According to four ENCB prominent female scientists that accepted to be interviewed, there are several factors that restrict the commercialization of their inventions. For example, for Dr. Maria Isabel Baeza-Ramírez her research on the treatment of diseases related to antibody agents is very promising. Yet, she acknowledges that her project continues in the development phase. Although she believes that biomedical firms should be interested in her research, at the moment there are no prospective partners to commercialize her invention. She sees the lack of funds as the main obstacle to her research.

For Drs. Alicia Ortiz-Moreno and Lidya Dorantes-Álvarez their research on the potential uses of a low-calorie avocado paste is encouraging. Although they already hold a national patent for their invention, the escalation to the industrial production level has been hard to achieve because of the demanding technical parameters asked by potential clients. They are nonetheless confident in fulfilling these conditions in the near future.

On her part, Dr. Eva Ramón is the first assignee of the patent WO2014051412 (A1), which was mentioned earlier in this chapter. Although she has already been approached by a pharmaceutical firm to commercialize her invention, the prospective alliance failed on the grounds of missed expectations. She reckons that more marketing expertise is still needed in order to detect the market niche to be exploited. She said that she also would like to get a more tangible institutional support from the National Polytechnic Institute.

Finally, for Dr. Sonia Mayra Pérez-Tapia, who has specialized in antigens, the commercialization of her invention should go away from the use of ENCB facilities in order to create an independent firm but the institutional inertia are so powerful that her colleagues are becoming increasingly risk averse, so she wants to focus on reinforcing the decision-making process instead of asking for stronger institutional support.

All in all, it is highly likely that most of these inventions can find a way to the market because of the quality and commitment of the researchers. However, several institutional, commercial and personal obstacles need to be solved, as for example, the lack of financial mechanisms to fund these endeavors, which, as pointed out above, has been a long-lasting weakness of the Mexican science and technology system. As regards the potential for commercial success, there is the problem of a lack of collaboration affinity between women researchers, as our patent analysis has demonstrated. This factor is crucial since Mexican women researchers seem to be heavily dependent on their male colleagues, who are more familiar with the patenting process, and the commercialization and creation of contacts with industry, to protect their inventions. It is worth mentioning that these conditions are highly consistent with those reported by Rosa and Dawson (2006) for the case of British universities.

One promising solution could be the encouragement of knowledge-driven clusters of start-ups and established small firms, as in the case of Cambridge and Oxford, in the United Kingdom. Another potential solution could be the fostering of intimate links with large pharmaceutical firms and publicly funded research centers, since these organizations are a key to spin-out businesses. Yet, these initiatives need some time to mature, and the specific problem at the moment is scale and the continuous flux of financial resources to support them.

Finally, from the five types of academic entrepreneurship that Louis et al. (Louis et al. 1989) distinguish, women scientists at ENCB seem to only consider two: securing patents and the commercialization of inventions based on their own research. In the case of patenting, one plausible explanation for this phenomenon is that the incentives provided by the SNI system have rewarded ENCB scientists more immediately and thus discouraging them to run the potentially risky commercialization of their inventions. Nonetheless, little by little, biotechnology firms have started to make noticeable strides on patent applications based on the research that they have funded in universities in Mexico (OECD 2009).

Conclusions

Commercializing knowledge involves transfer from discovering scientists to those who will develop it commercially. Team production allows more knowledge capture of tacit, complex discoveries by academic scientists. By analyzing the situation of women's role in academic entrepreneurship in Mexico, it was possible to identify the main barriers that female scientists normally face to commercialize their inventions. As pointed out by Brush (2008), gendered and stereotypical assumptions about women participating in business reinforce and perpetuate the idea of entrepreneurship as a male construct and limit our understanding of entrepreneurship and entrepreneurial behavior in its many forms and contexts. The extant literature on women in science and technology suggests that female faculty had a lower percentage of industry publications, industry collaborations, and patents than their male colleagues and a smaller percentage of women engage in any patenting. Empirical findings from this paper do confirm these impressions. This is a critical phenomenon since global trends in business show that there are increasing opportunities for academic scientists to commercialize their science.

In the case of Mexico, women scientists and entrepreneurs still underperform compared to their male counterparts. One reason for this is that the Mexican academic milieu is still dominated by men. Male scientists can be found in a majority of places, either as heads of scientific departments, as members of leading research groups or keeping high bureaucratic posts. This structure has created a sort of "cultural inertia," that female scientists see as "natural" when it comes to put themselves as subordinates of leading male researchers. There are several negative consequences of this structure. Firstly, female scientists may feel uncomfortable seeking to explore independent research paths without asking for "expert male advice." Secondly, they are unable to venture into profiting from their research work because they have not had enough time and opportunities to familiarize with the subtle world of "business relations" needed to seek for funding, a condition that is highly valuable in the Mexican context, where personal relations (i.e., social networks) are essential. Thirdly, there still are institutional hurdles in most Mexican universities for female scientists wishing to raise children. Although a number of social benefits for caring women have been institutionalized; tenure requirements, attached to institutional factors for keeping a high academic profile, still exert a considerable pressure.

On the other hand, empirical results suggest that female researchers at the ENCB have not yet constructed strong social networks as to become interdependent among them. That is, they still rely on their male colleagues to publish and patent. So, they should increase the number of new collaborations, especially with more numerous teams. Besides, the creation of new technology-based business from female scientists' work is very rare. Only a handful of ventures have been initiated, and most of them are still in the start-up phase, as seen in the previous section. To women at the ENCB, the potential for new business ventures is enormous, however. They have already achieved a critical mass for joining entrepreneurship ambitions thanks to the strides made by their leading colleagues. The ENCB, as reported in the fifth section, has the largest concentration of female SNIs in the IPN. That is a considerable social achievement, after considering that the institution is still male-dominated. So, a more decisive institutional support for their women entrepreneurs would be welcomed.

In this respect, we should stress that even though female scientists tend to be more cautious, thorough and attentive to detail in preparing work for publication, this attitude can be counterproductive in patenting since market conditions put a tremendous pressure on inventors to protect their intellectual property as soon as possible. Therefore, public policy should introduce stronger incentives as to encourage female scientists to join and collaborate more on research projects with an eye put on learning and gaining confidence in their research. Besides, the introduction of stronger gender-equity measures in the design and conformation of research panels, assessing bodies and any other agency devised to evaluate research proposals is also welcomed. Additional policy measures should go in the direction of considering the introduction of wider social benefits (together with softer institutional requirements) for scientists wanting to rear children.

Empirical evidence reported here shows that female scientists at the ENCB are as capable as men to patent and commercialize their inventions. This is an important issue since Mexican women have much to contribute as inventors, technologists, managers as well as entrepreneurs but the country's higher education system has not yet explored entrepreneurship for women with scientific training as an alternative to careers where the glass ceiling remains.

In order to encourage Mexican scientists to commercialize their inventions since a gender lens, a set of policies should be implemented. There are internal and quasi-internal approaches (e.g., incubators), university research parks, regional clusters, academic spin-offs and start-ups, licensing, contract research and consultancy, corporate venture capital, and open science and innovation. We propose areas for further research at the individual level (e.g., heterogeneity of female entrepreneurial teams and experience; incentives for the creation of science-based business), organizational and intra-university levels (e.g., corporate governance; nature of growth strategies; relationships with trading partners; boundary spanning activities) and at the technology levels (e.g., the permanent assessment of the institutional context; the dynamics of the technological change and its impact on women's entrepreneurial initiatives; valuation of technology).

Finally, more research is also needed in relation to the role that social networks play in boosting entrepreneurial attitudes among female scientists. Some potential new lines of research can be established around the way collaborative relationships are created, nurtured and developed in the case of Mexican female scientists. This area can be of great importance in the near future as the role of crowdsourcing as a mechanism for promoting innovation has been gaining acceptance in many academic circles.

Notes

1. Further details on the history and academic achievements of the National School of Biological Sciences can be accessed through its webpage at http://www.encb.ipn.mx [Retrieved on April 24, 2015].
2. See Villa, 2009, p. 51.
3. The requirements asked by CONACyT for acquiring the SNI membership can be consulted at http://bit.ly/1j3GJ8L [Document in Spanish, and accessed on October 27, 2015].

4. Although we do not actually have hard evidence for this behavior, we can put forward four possible hypotheses for it. (1) The costs for patenting in Mexico are far lower than those for patenting abroad. (2) The first (and most important) market for ENCB scientists to commercialize their inventions is Mexico. (3) Since Spanish is the only language spoken by the majority of Mexicans there are considerable tongue barriers to apply for patent protection in foreign markets, such as that of the United States. (4) Productivity requirements for registering into the SNI system value all patents equally, regardless of the country of assignation.
5. This situation has been growing in importance since two thirds of Mexican households are now female-headed. To get access to further details on this phenomenon see the May 12, 2012 UNAM's bulletin (in Spanish) at http://www.dgcs.unam.mx/boletin/bdboletin/2012_297.html [Retrieved on October 29, 2015].
6. For further details on this business venture, see the report "The History of Transfer Factor" (Historia del factor de transferencia, in Spanish) at the URL http://www.factordetransferenciaipn.com.mx/historia.htm [Retrieved on October 29, 2015].

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4

Patenting Activity in Spain: A Gender Perspective

Elba Mauleón and María Bordons

Introduction

The collection of science and technology indicators by gender is currently being encouraged at a national and supranational level to determine the status of women in scientific and technological research. Women are underrepresented in science, since they roughly account for one-third of researchers in some regions, such as the European Union (EU-27) (33%) (European Commission 2013) and the United States of America (US) (28%) (National Science Board 2014), and even a smaller proportion in other countries such as Japan (13%). Women underrepresentation in science is an issue of deep concern not only because gender equality needs to be guaranteed but also because women's human

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capital is considerably underutilized and all countries should employ the full range of their potential human resources to become competitive.

The presence of women is especially low in industrial research and in activities related to technological innovation. In fact, 40% of all researchers employed at public research centers and universities of the EU-27 are women, while their share among industrial researchers slumps to around 19% (European Commission 2013). Moreover, there are differences by country in the proportion of women researchers, but the degree of cross-country disparity is wider in the private sector than in the public or tertiary education sectors. Thus, in the European private sector (EU-27), women represent less than 15% of the research population in three countries (the Netherlands, Germany, and Luxembourg), but around 40% in other countries (Romania, Bulgaria, and Croatia). In any event, in all EU countries the rate of female researchers in the industrial sector stands far behind that of the public sector.

There is a series of factors accounting for the low proportion of women in industrial research. First of all, there are educational factors that have to be addressed. The female participation rate in industrial research is closely related to women's rate of university graduates, and the share of women graduates in technology-oriented fields, which are the most demanded in the industrial sector, remains relatively low. Personal factors also play a significant role, since female's lack of self-confidence may prevent women from applying for specific jobs in the industrial sector. Other difficulties hindering the development of a professional career in the industrial sector are derived from the lack of role models and the struggle to reconcile family and working life, both of which also are partly responsible for the low presence of women in industrial research. In addition, there are entry barriers, namely a bias in corporate recruiting and hiring practices that has been described in the past. Finally, the fact that women quit their jobs in the industrial sector more often than men suggests they may perceive the working atmosphere as unfriendly. The prevailing male culture in the industrial sector may lead to women suffering from isolation and exclusion from informal networks which may also help to account for their higher attrition rates and slower career progression (Rübsamen-Waigmann et al. 2003).

Collecting detailed sex-disaggregated statistics on research and development (R&D) is required to detect gender imbalances and to assess the effectiveness of the set of policy measures in place to achieve gender equity. In this sense, "*She Figures*", a triennial publication first released in 2003, is an interesting initiative, since it aims at building comparable statistics between EU countries in order to monitor the relative position of women in science and technology. In the US, "*Women, Minorities, and Persons with Disabilities in Science and Engineering*" (National Science Foundation 2013), a biennial publication, provides statistical information about the participation of women in science and engineering, education, and employment. However, quantitative approaches need to be supplemented by qualitative studies which explore factors that favor gender inequality in science and technology and are useful to identify the best practices available to improve the situation of women in industrial research. As regards quantitative approaches, a majority of studies address the use and development of input-based indicators involved in the research process (for example, the percentage of female researchers in industry, the percentage of women in specific technological sectors, etc.), while output-based studies, which analyze aspects such as patent productivity or the impact of inventions, are far less frequent.

Patents are widely accepted as valid indicators of inventive and innovative activity, although they are subject to a series of limitations which has been repeatedly described in the literature (Griliches 1990; OECD 2009). Among them, it is worth noting that not all inventions are patented; the propensity to apply for patents varies across countries, sectors and technology fields; patents may differ largely in their value; the dissimilarities between national patent systems due to legal, geographical, economic and cultural factors (dubbed as the 'home advantage') may restrain patent use as innovation indicators. The above notwithstanding, patent documentation is a unique source of information to analyze and monitor the technological performance of countries, regions, institutions, and even companies and individual inventors.

The study of patenting activity by gender is hindered by the problematic identification of an inventor's gender from his/her name since their sex is not disclosed in patent applications. This issue has been dealt with in the literature in various ways: sometimes, the gender of inventors may be inferred from their surnames (Azoulay et al. 2007; Mauleón and Bordons 2010; Sugimoto et al. 2015), while in other cases it may be directly disclosed by the researchers themselves in surveys or interviews (Morgan et al. 2001; Hunt et al. 2013). A register of names in different European languages with the gender associated with each name was first developed by Naldi et al. (2004) and has been used by other authors since Frietsch et al. (2009). In the US, different sources of male and female names from all over the world were used as gender allocation tools for the inventors registered in the US patent database in a study conducted by the National Women's Business Council (Delixus 2012) and approximately 94% of the names were successfully identified. This study mentioned a number of limitations, such as the inclusion of initials instead of first names in some patents and the fact that some names are indistinctly used for both men and women. The need for gender identification and the lack of normalization of inventor's names in patent applications are factors which hinder the development of patent-based studies by gender. Furthermore, since coping with these difficulties is no easy task, studies developed at the micro level (e.g., Ding et al. 2006) prevail over large-scale ones (e.g., Naldi et al. 2004; Frietsch et al. 2009).

In the context of research at the macro level, a pioneering study funded by the European Commission on the inclusion of the gender variable in studies of scientific and technological activity was conducted by Naldi et al. (2004). Scientific publications and patents applied for from six European countries (United Kingdom, France, Germany, Italy, Spain, and Sweden) at the European Patent Office (EPO) in 1998 were analyzed with a focus on the engagement of men and women as researchers and inventors. A significant gender gap was observed. Said gap turned out to be narrower in science than in technology: 97% of patents had at least one male inventor while only 12% were authored by at least one female inventor. When only scientific publications were considered, 95% of them had at least one male author whereas a minimum of one female author was present in 46% of the publications. In addition, a number of differences by country and field were described in the study: Spain, France, and Italy claimed the highest rate of female involvement both in science and in technology while Germany obtained the lowest scores. These results were consistent with the share of female workers in the public sector of the countries of reference, with Spain topping the list and Germany closing it at the bottom.

Some substantial differences across countries were also observed in the study of Frietsch et al. (2009) based on scientific publications covered by the Scopus database and EPO patents for 14 countries in a selection of years from 1993 to 2005. Women's relative contribution to technology was found to be lower than their contribution to science and central European countries, and Germany, Austria and Switzerland, in particular, obtained the lowest rates (3–5%) far behind the countries leading the score table, namely Spain, Italy, and France, (10–12%). Industrial sector and research structure dissimilarities along with the specialization of countries were set forth to account for country-specific differences.

An analysis of European inventors in patents applied for at the EPO during the period 2001–2003 showed that only 8% of them were women (Busolt 2009). Women's invention activity was particularly high in Chemistry and health-related disciplines, but even in these fields women were found to be underrepresented. The comparison of the geographical distribution of inventors with the share of female inventors by country revealed that the proportion of female inventors was higher in countries with weak patenting activity (Southern EU countries) whereas countries with strong patenting activity present low shares of female inventors (e.g., Germany). Interestingly, Busolt's study included an online survey to get some insight into the innovation climate in organizations applying for EU patents and found out that most of the respondents were not familiar with equal opportunities policies and that both general working conditions and the innovation climate favored male researchers. Accordingly, increasing the numbers of women in science and technology did not suffice to shore up female involvement in inventive activity, an improvement of working conditions and access to resources was also required (Busolt and Kugele 2009).

As far as large-scale studies are concerned, it is worth mentioning a US countrywide report on the participation of women in patents and trademarks based on data filed with the United States Patents and Trademarks Office from 1975 to 2010 (Delixus 2012). Its major findings showed several positive results: an upward trend in the number of patents granted to women; a surge in the leadership of women, which appears more frequently as primary patent holder late into the period; a growing ratio of successful female patent applicants to successful male patent applicants, which rose from around 73% in 1986 to 94% in 2002. Curiously, women had a significantly higher participation in trademark activity (33% of trademarks in 2010) than in patent activity (18% of patents granted in 2010), maybe due to differences in employment patterns, R&D opportunities, and risk and reward perceptions.

More recently, gender disparities in patenting by country, technological area and type of assignee in patents issued between 1976 and 2013 by the United States Patent and Trade Office (USPTO) were analyzed by Sugimoto et al. (2015). Women accounted for less than 8% of all inventions during the entire period, but their patenting rate showed a clear increase all along. Women patenting was more likely to occur in academic institutions than in companies or governmental entities, this being a persisting trend over the whole period of reference.

In response to the interest raised by macro-scale studies at the country level, this paper provides an analysis of Spanish technological activity by gender considering patent applications filed with the EPO, addressing the following set of research questions: What is the involvement of men and women as inventors? Do women tend to concentrate in specific institutional sectors and fields? Are there differences by gender in collaboration patterns? Is the gender gap narrowing over time? This type of study can be relevant not only for scholars but also for research managers and policy makers interested in monitoring female presence in technological activity. It may enable the development of informed policies and practices oriented to promote gender equality in technological research. There are former studies in the literature dealing with Spanish technological activity by gender in different databases and periods (Mauleón and Bordons 2010; Mauleón et al. 2014; Mauleón and Bordons 2014). This study goes beyond a previous one, in which only patents with all their inventors from Spain were analyzed (Mauleón and Bordons 2014).

Methodological Aspects

This paper focuses on patents with at least one Spanish inventor applied for at the EPO during the 1999–2007 period. The following different types of applicants were defined: Industrial Sector, Individuals, Spanish National Research Council (CSIC), Universities, Other Sectors (including non-profit organizations), and Foreign Applicants. Since the information on the applicants is not standardized in the original database and each institution may appear under different names, institutions were codified using a semi-automatic algorithm allowing subsequent automatic counts (Morillo et al. 2013). The total counting method was used to allocate patents to applicants so that if two or more types of applicants appear in a given patent application, such patent is assigned to each of them.

The sex of inventors was established according to their full name, either because it was contained in the patent database or because it was obtained externally by means of internet searches, with special emphasis on institutional and personal webpages. Sex identification procedures proved to be a laborious task, but they were successful in 98% of the patent applications under examination.

A series of different measures previously described by Naldi (2004) were applied to the study of the technological activity of male and female inventors: (a) participation: the percentage of patents signed only by men, only by women, or by male and female inventors; (b) contribution: it is based on fractional counts. In a patent with n inventors, the contribution of each inventor will be 1/n. Therefore, the sum of all inventors' contributions will be 1 and individual contributions will have values between 0 and 1. For example, in a patent with four inventors, three men and a woman, female and male contribution will be 0.25 and 0.75, respectively. Contribution is also called 'patents equivalent' since it sums up the individual shares in each item attributed to a given gender; (c) presence: the percentage of men and women as inventors of patents.

To study differences by gender in the specialization profile of inventors, use has been made of the thematic codes that describe the content of the patents. These codes correspond to the International Patent

Classification (IPC) established by the Strasbourg Agreement in 1971 and based on a hierarchical system which classifies patents according to different areas of Technology. IPC codes were re-classified according to the OST/INPI/ISI Classification (Schmoch 2008), which provides a better match with economic activities. Five main technology fields were retained. Since patents may have more than one IPC code, they can be also assigned to more than one technology field.

Given the interest of some technological domains as drivers to boost the competitiveness and economic growth of countries, the presence of men and women in three emerging technology fields is explored: Biotechnology; Information and Communication Technology (ICT); High Technology, as they have been delimited under Eurostat criteria (http://ec.europa.eu/eurostat/cache/metadata/Annexes/pat_esms_an4.pdf). ICT includes, but is not limited to, telecommunications, consumer electronics, computers and office machinery, while the following technical fields are defined as part of the High Technology field: computer and automated business equipment; micro-organism and genetic engineering; aviation; communications technology; semiconductors; lasers.

Collaboration plays an increasingly important role in science and technology. This can be explained by the changing nature of scientific work, where specialization, interdisciplinarity, and data and facility sharing practices have acquired growing importance (Katz and Martin 1997). The following indicators were used to study the presence of joint inventions and team research in innovation: (a) percentage of male and female sole-inventor patents; (b)co-inventorship index, which is the average number of inventors per patent.

Binomial logistic regression was used to understand whether female presence could be predicted on the basis of certain variables, such as the number of inventors, the thematic classification of patents, the institutional sector and its publication year. The dependent variable "female presence" was measured on a dichotomous scale—"at least one female inventor" or "no female inventor". SPSS software, version 22, was used for the statistical analysis of data.

Our study focuses on patent applications, but for the sake of simplicity, the terms "patent" and "patent application" are used as synonyms.

Moreover, although we are aware of the differences between the terms "sex", which refers to the biological differences between women and men, and "gender", which is a socio-economic and cultural construct, both terms are used indistinctly throughout this paper.

Empirical Data

During the 1999–2007 period, a total of 8,623 patent applications with at least one Spanish inventor were filed with the EPO. The number of patent applications rose from 521 in 1999 to 1,490 in 2007, which amounts to a threefold increase during the period. As for the type of applicants, the highest activity was found to pertain to the industrial sector (50%), followed by individuals (16.5%), University (3.5%) and the Spanish National Research Council (CSIC) (2.6%), while a foreign applicant was identified in nearly one-third of the patents (30.2%). The major technological fields involved were Mechanical Engineering (36.1%), Chemistry (32.4%), Electrical Engineering (16.8%) and Instruments (11.9%). The increasing role of collaboration in inventive activity was evidenced by the ascending trend of the average number of inventors per patent (from 2.12 in 1999 to 2.60 in 2007) and the declining percentage of sole-inventor patents (from 53.9% in 1999 to 39.9% in 2007).

The study of Spanish technological activity from a gender perspective was based on patents where each inventor's sex had been successfully identified (8418 patents; 98% of the total). During the whole period, only 3.2% of the patents were signed only by women, compared with 75.7% signed only by men, and 21.1% signed by mixed teams; that is, 24% of the patents had at least one female participant. In fractional counting terms, women contributed to 11.2% of the patents. Furthermore, 15.9% of the inventors were women and 84.1% were men. Throughout the period, a modest increase in female presence is observed (Fig. 4.1). This is more evident with regard to the female participation rate (the percentage of patents with at least one woman climbed from 20% in 1999 to 28% in 2007) while the upward slope is very smooth in fractional count terms (female contribution only rose

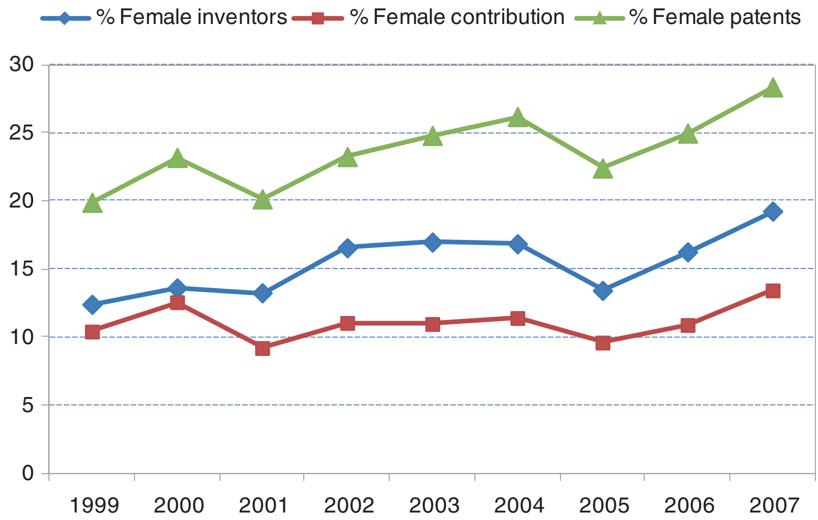

Fig. 4.1 Yearly evolution of women involvement in patent applications

from 10% in 1999 to 13% in 2007). The fact that women step up their participation rate mostly as co-inventors with male colleagues contributes to explain the higher growth of female participation as against female contribution.

Female Presence by Type of Applicant

Large differences in female involvement are observed depending on the applicant's institutional sector (Table 4.1). Women are more likely to appear in University and CSIC patents, while their involvement rate is very low in patents owned by industrial private companies and, particularly low, in those granted to individuals. The set of indicators that have been used provide convergent but not redundant results, since they supplement each other. Lower values are obtained for female contribution as against female patents because contribution is a fractional count which takes into account the number of women in each patent which is usually smaller than the same for men. Female participation, contribution and presence show very similar values in the case of individuals,

Table 4.1 Female involvement in patents by institutional sector (EPO, 1999–2007)

	No. patents	% Female patents	% Female contribution	No. inventors	% Female inventors
Industrial sector	4213	18.97	9.04	9236	15.00
Individuals	1385	11.91	9.76	1775	9.86
CSIC	217	62.21	2.10	885	27.80
University	294	58.50	24.47	1192	28.10
Foreign applicants	2541	34.91	13.25	9076	15.86
Other sectors	92	55.43	20.96	359	22.84
Total	8418	24.31	11.19	21156	15.93

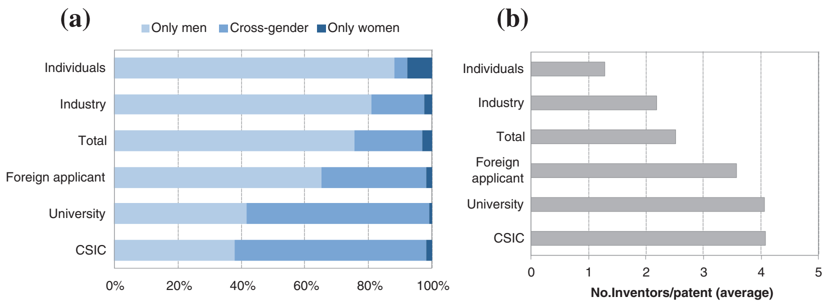

Fig. 4.2 Gender differences by institutional sector: (a) Participation of male and female inventors in patents. (b) Average number of inventors per patent

because sole-inventor patents are the norm for this type of applicant. On the contrary, large differences in participation, contribution and presence rates have been found for University and CSIC patents, where participation values more than double contribution values, probably because collaboration plays an important role in research carried out in these organizations (see Fig. 4.3 on the average number of inventors per patent) and women tend to co-operate with male colleagues.

As regards participation, cross-gender teams predominate for applications from University and the CSIC, while only-men patents account for at least 80% of the patents owned by individuals and companies in the industrial sector (see Fig. 4.2). In order to fully understand this point, it should be noted that 52% of patents pertaining to the industrial sector and 81% of those owned by individuals are sole-inventor patents and, consequently, a large proportion of only-men patents in these two sectors have been developed by a single inventor.

Female Presence by Field

Female involvement in patents also varies according to fields (Table 4.2), displaying the lowest values for Mechanical Engineering and the highest for Chemistry. These measures are consistent with the results of previous studies on European patents (Naldi et al. 2004; Frietsch et al. 2009). In our study, female participation more than doubles female contribution in most fields due to the important role of teams (Fig. 4.3) in the development of research and the predominance of men as team members.

With regard to participation, only-men patents predominate in all fields, ranging from 52% of patents in Chemistry to 89% in Mechanical Engineering. Overall, only-men patents account for 76% of the total, while cross-gender teams appear in 21% of them and merely 3% of the patents are invented only by women. The highest presence of cross-gender patents is observed for Chemistry (44%), which is also the field where the largest teams have been found (see Fig. 4.3).

If we turn to patenting activity in emerging areas of technology, patents in Biotechnology, Information and Communication Technologies and High Technology are found to, respectively, represent 5, 14 and 11% of

Table 4.2 Female involvement in patents by field (EPO, 1999–2007)

	No. patents	% Female patents	% Female contribution	No. inventors	% Female inventors
Electrical Engineering	1411	17.51	7.21	3360	9.20
Instruments	998	22.75	9.58	2448	13.73
Chemistry	2729	47.82	20.70	9886	24.77
Mechanical Engineering	3041	12.17	6.04	6009	7.95
Other fields	1480	10.14	7.28	2280	7.63
Total	8418	24.31	11.19	21156	15.93

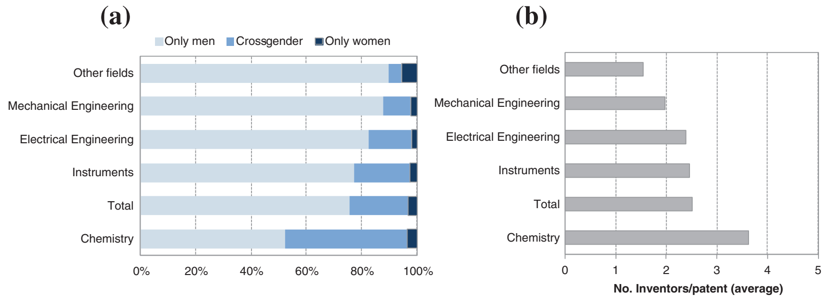

Fig. 4.3 Gender differences by field: (a) Participation of male and female patentees. (b) Average number of inventors per patent

the total number of patents. Biotechnology posts the highest rate of female activity (29% of inventors are women) followed by High Technology (14%) and Information and Communication Technologies (8%).

Collaborative Practices by Gender

A higher propensity of women to collaborate with other inventors has been observed. Overall, women are responsible for 5% of sole-inventor patents, while their share in team-developed patents shows a steep rise to 18%. Could this result be due to the smaller presence of women in patents owned by the industrial sector or individuals where sole-inventor patents are more common? Our data suggest that this may well be an influential factor, but not the only one, since the lower presence of women in sole-inventor patents is apparent in most of the institutional sectors and fields under study. In fact, this would rather support the view that women actually have a higher propensity to collaborate (see Fig. 4.4).

Multivariate Analysis to Explain Female Presence

A logistic regression was used to jointly assess the effect of different variables on the presence of women in patents. In particular, we would like to ascertain the impact of variables such as the institutional

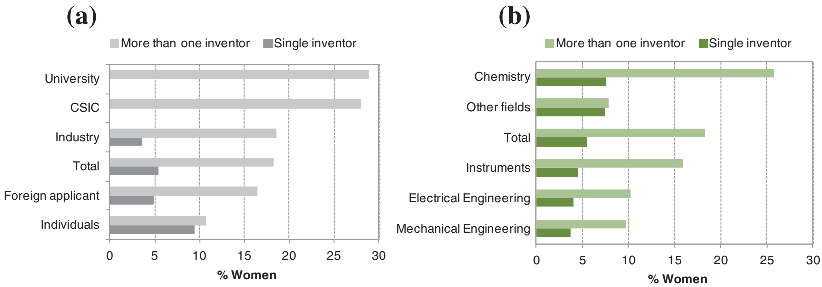

Fig. 4.4 Presence of women in sole-inventor and team-developed patents by (a) institutional sector and by (b) field (EPO, 1999–2007)

Table 4.3 Logistic regression model

	B	Wald	Sig.	Exp(*B*)
Industry	−0.733	39.944	0.000	0.481
Individuals	−0.332	5.530	0.019	0.718
Foreign applicant	−0.601	26.665	0.000	0.548
Chemistry	1.002	199.254	0.000	2.724
Mechanical_Engineering	−0.504	42.716	0.000	0.604
Other_Fields	−0.299	8.148	0.004	0.742
Biotech_patents	0.275	4.939	0.026	1.316
No.Inventors	0.505	743.666	0.000	1.657
Constant	−2.226	282.677	0.000	0.108

Note *B* = estimated value of the regression coefficient, Wald = Wald statistic, Sig = level of significance, Exp(*B*) = Odds Ratio. Only significant variables are shown

sector, the technological field, the number of inventors, and the publication year on the likelihood that patents have female inventors (see Table 4.3). The logistic regression model was statistically significant ($p < .0005$); it explained 37.6% (Nagelkerke R^2) of the variance in female presence and correctly classified 76% of the sample cases. Chemistry patents are 2.7 times more likely to include female presence than the rest of the patents, while the likelihood of having female inventors in Mechanical Engineering is 40% lower than in the rest of the patents under examination. An increase in the number of inventors involved in a given patent correlates with a higher probability of female presence in the team. Patents from the industrial sector, individual persons and foreign applicants are less likely to include female inventors

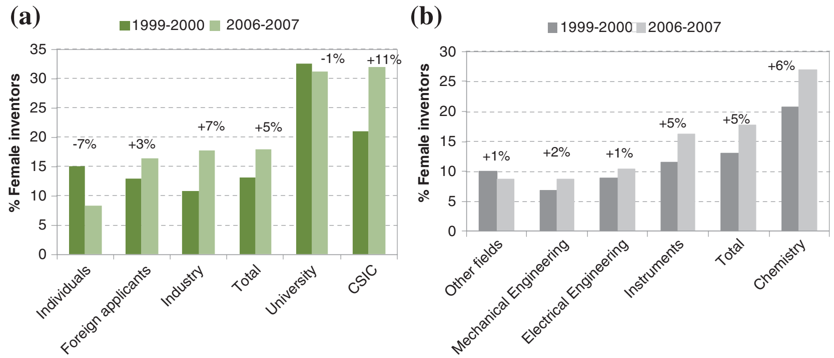

Fig. 4.5 Change over time in the percentage of female inventors by: (a) institutional sector and (b) field (EPO, 1999–2007)

(52, 28 and 45%, respectively). The publication year was not found to be a significant variable.

Although the publication year is not significant within the context of the logistic regression model, it is interesting to explore whether there are interfield and/or interinstitutional differences in the evolution of female presence over time. Data from 1999–2000 were compared with 2006–2007 data (see Fig. 4.5). Since a small number of patents were associated to specific sectors and/or fields, data encompassing 2-year periods were preferred against single year data in order to obtain more reliable results. Overall, the percentage of female inventors grows from 13% in 1999–2000 to 18% in 2006–2007. By institutional sector, the highest growth rate corresponds to the CSIC (+11%), followed by the industrial sector (+7%), while female presence among individuals tends to decline over time (−7%). By field, it is Chemistry that scores the biggest gain (+6%).

Discussion and Conclusions

This study shows that patent-based indicators by gender are useful to monitor the presence of men and women in technological activity. However, there are several methodological limitations worth noting, such as the lack of data normalization on the name of inventors and applicants—either individual or institutional—and existing difficulties hindering the identification of inventors by sex. The use of databases including collections of the most common names in different countries has proved useful to determine the sex of inventors in a number of studies (see, for example, Naldi et al. 2004; Delixus 2012), but it is not free of noteworthy limitations, such as the fact that some names are used for both men and women indistinctly, the appearance of new names in a given country due to immigration reasons, the changes in most common names over time, and the different variations of same-name spellings, all of which may hinder sex identification in some cases. Although the identification of specific inventors was not necessary for the purposes of this study, the lack of normalization of inventor names poses an additional problem which has attracted great concern in the literature since it reduces significantly the accuracy and reliability of studies and statistics concerning individuals. To cope with this problem, a number of useful mathematical algorithms enabling name disambiguation have been recently described (see, for example, Li et al. 2014). Whatever the case, applicants and patent offices should be aware of the interest of recording normalized names of individuals and institutions.

In Spain, women remain a minority in technological activity as measured by their presence as inventors in patent applications filed with the EPO during 1999–2007. Only 16% of inventors are women, just 24% of patents have at least one female inventor and this figure slumps to 11% in fractional count terms. The low fractional count is due to the fact that women usually collaborate with men in their inventive activity. Therefore, it is not striking that women are found to be sole inventors in only 3% of the total number of patents while they appear as members of cross-gender teams in 21% of them. At any rate, these figures are quite low if we consider that the proportion of women researchers in Spain was about 37% in 2006 (European Commission 2009).

Female involvement in technology is lower than in science. As a matter of fact, women participate in 24% of patents but in 60% of Spanish scientific publications in the Web of Science (Moya-Anegón et al. 2008; http://eprints.rclis.org/16642/). This may be partially due to the lower proportion of women in technology-oriented fields as has been described for different countries and employment sectors in the past. Thus, within the EU-27, in 2006 women accounted for 50% or more of the total number of Ph.D. holders in most broad fields, and yet only represented 25% of Ph.D. holders in Engineering, Manufacturing and Construction (European Commission 2009). The scarce number of women in these fields has been also described for countries such as the US (21%), and becomes even more glaring in other countries such as Japan (11%). Interestingly, differences by country do exist even among European Union Member States themselves. The existence of a negative correlation between the proportion of female inventors and the development of a country's national system of innovation has been described in the literature (Busolt and Kugele 2009). The high activity carried out by the industrial sector (where women are usually a minority) in countries with a strong national system of innovation (e.g., Germany) is an explanatory factor.

This study has disclosed evidence of the uneven distribution of female inventors across institutional sectors, showing a higher presence of women in the public sector (University and the CSIC) than in the industrial sector and among individual applicants. This is fully consistent with the higher presence of female inventors in academic institutions as described by Sugimoto et al. (2015) for patent applications filed with the USPTO. In the present study, the weak inventive activity of University and the CSIC (around 3% each out of the total number of patents) contrasts with their strong performance in scientific production: Universities are responsible for more than 60% of Spanish scientific publications in the Web of Science, while the CSIC accounts for 17% of such publications (González-Albo et al. 2012). The CSIC, which is Spain's main public research body, conducts research in all fields of knowledge, encompasses both basic research and technological developments, and is the Spanish public research organization holding the higher number of patents granted by the EPO. Nonetheless, University and public research organizations are poorly involved in patenting in Spain. The comparison of the proportion of women in the Spanish labor force with the corresponding rate among inventors by institutional sector shows us that the involvement of women in patents is lower than expected. In the industrial sector, women represent about

29% of researchers (INE 2010), but only 15% of inventors, whereas, in University and public research organizations, the percentage of women inventors is higher (around 28%), although this share stays well below the share of women researchers (around 40% in 2010) (INE 2010). These data indicate that women are less likely to apply for a patent (as also described by other authors: see, for example, Bunker Whittington and Smith-Doerr 2005; Ding et al. 2006; Hunt et al., 2013) even in the sectors where they are better represented.

Gender differences in patenting in the academic sector have been under consideration in different studies in the literature. The fact that female academics are less likely to participate in commercial and entrepreneurial activities than their male counterparts has been described in the past and is related to personal and contextual factors (Bunker Whittington and Smith-Doerr 2005; Stephan and El-Ganainy 2007). The stronger risk aversion of women, their less competitive attitude, and their activity in "small" areas with weaker commercial outlets have been mentioned to be some of the personal factors underlying such situation. Besides, the weaker integration of women in diverse networks has been considered a contextual factor that reduces their chances to participate in commercial and entrepreneurial activities. Not only women are less frequently invited to participate in entrepreneurial endeavors but also the time spent in patenting activities may turn out to be costlier for them because of their fewer contacts with the industrial sector and their weaker business experience. Moreover, the stronger concern raised among women by the possible negative impact of patenting on their academic career has also been described, although this attitude is on the wane among younger scientists and "patenting is increasingly viewed as a legitimate means to disseminate research" (Ding et al. 2006). Fostering women integration in scientific networks and promoting the activity of technology transfer offices in the academic sector have been suggested as useful actions in order to enhance women engagement in patenting in the sector.

As regards the industrial sector, the need to introduce organizational and cultural changes so as to encourage female patenting has also been put forward in the literature. There is a need to implement initiatives oriented to avoid gender-biased recruitment practices, to facilitate work and personal life reconciliation, to promote cross-gender teams, and to improve women integration in networks as part of the "good practices" that companies should apply to attract, retain and promote women in research (Rübsamen-Waigmann et al. 2003).

In our study, patents in Chemistry are more likely to present female inventors, while the opposite situation holds in Mechanical Engineering. These results are consistent with those of Naldi et al. (2004) and Frietsch et al. (2009) concerning European inventors, as they found that the Pharmaceutical field was the one with the highest female contribution rate, followed by the Basic Chemistry field, with the Engineering Technologies field down at the bottom of the list. The differences in the thematic profile of male and female inventors can be related to gender disparities in the selection of study fields. The fact that women are more likely to have a degree in less patent-intensive fields contributes to explain their weaker inventive activity. Various strategies such as avoiding gender inequality in education and encouraging young women to select technology-oriented fields have been proposed to foster gender balance by field (Caprile 2012). However, as stated by Busolt and Kugele (2009), increasing the number of women in technology-oriented fields is not enough to ensure their integration in innovation activities and further actions with a view to improve their working conditions are required.

With regard to the activity of female inventors in emerging technology areas, it is worth noting that women are underrepresented in High Technology and ICT, while they show a relatively high activity in Biotechnology. In theory, emerging research areas could prove positive for women due to their more flexible organizational models (Whittington and Smith-Doerr 2008). However, a certain level of female presence, such as the one observed in Life Sciences and, in particular, in Biotechnology, is probably required in order to reap the full benefits of new organizational structures. Anyway, there is an obvious interest in attracting women to these fields which have become important drivers for the competitiveness and economic growth of countries.

This study shows an increase in collaboration between inventors as may be inferred from the growth rate of both the co-inventorship index and the percentage of team-developed patents. This is consistent with the global shift towards teamwork described for a large majority of scientific and technical fields, as evidenced by the increasing mean number of authors per article (Gazni et al. 2012) and the growing share of team-developed patents (Wuchty et al. 2007). Scientific collaboration is essential in modern science since it enables scientists to share knowledge, expertise and techniques, and also cope with increasingly interdisciplinary and sophisticated research (Katz and Martin 1997). Our data reveal that the co-inventorship index varies by institutional sector and field because it depends on the organizational structure of centers and on the specific demands of each discipline, but women tend to participate in larger teams than men in most fields. These larger sized teams have been also described in other studies (Busolt 2009; Jung and Ejermo 2014) and require further scrutiny. On the one hand, it may be due to personal factors such as a stronger female penchant for collective practices compared to men, who are more frequently bent on individual achievement (Bunker Whittington and Smith-Doerr 2008). However, it raises additional questions about the role played by women in research teams. To what extent do women hold a leadership position in teams? Do they appear less often than men as sole inventors because of a higher propensity to co-operate? Or is it all a consequence of the lower autonomy of women who are wont to play a secondary role in research? Whatever the case may be, cross-gender teams can be a positive driver for research performance since gender diversity may enhance creativity and collective intelligence and thus contribute to enhance innovation (Bear and Woolley 2011). Therefore, diversity should be encouraged not only for egalitarian reasons, but also for economic purposes (improving efficiency and competitiveness), and to improve the quality of research. Interestingly, diversity is currently considered a key element of sound management of research and innovation policies (Caprile 2012).

Although the presence of women in EPO patents has increased over the 1999–2007 period, progress is very slow (data since 1990 are available from Mauleón et al. 2014). The fact that the strongest rise in the percentage of female inventors is observed in institutional sectors (CSIC) and fields (Chemistry) which also had a relatively high female presence at the beginning of the period suggests that we are in the midst of a slow transition process in which major changes do not take place.

However, the relatively strong increase of female presence in both the industrial sector and the Instrumentation field are positive findings which suggest that diversification is making headway in the institutional and thematic profile of women.

In summary, this study provides evidence of the existence of a significant gender gap in patenting activity in Spain, although a narrowing trend has been observed throughout the 9-year period of reference. As has been repeatedly shown, gender imbalances unfavorable to women in research are not self-correcting phenomena and the implementation of policy measures to promote female participation in patenting and commercial research is essential. Our study shows that the collection of sex-disaggregated indicators on patenting activity is useful to monitor female presence and to identify fields and sectors where gender inequalities are more pronounced. In addition, this type of study may contribute to assess the effectiveness and impact of policy interventions. Studies at different levels of analysis (macro and micro) and from different perspectives (quantitative and qualitative) are required and supplementary to one another to acquire further insight with regard to the situation of women in science and technology and provide a sound basis for policy making.

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Elba Mauleón holds a Ph.D. in Information Science: Archives and Libraries in a Digital Environment from the Carlos III University of Madrid. Her lines of research cover a broad scope of topics including women in science, women in technology, and women in top positions in science. She has participated in different research projects dealing with bibliometric indicators by gender as well as in many international academic workshops. She has co-authored scientific articles and book chapters in national and international peer-reviewed channels.

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5

Gender Patterns of Businesses with Growth Potential in Croatia

Slavica Singer, Nataša Šarlija, Sanja Pfeifer and Sunčica Oberman Peterka

Introduction

Innovative businesses are an elite minority in any developed or developing economy, and are essential for building sustainable competitiveness, creating new jobs, well-being, and fair societal infrastructure.

Both women and men are expected to bring innovation in all aspects of our lives, but there are less women in those activities across the world than it would be expected according to the women's population share.

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This is also the case in Croatia, a country experiencing mega changes of the political, economic, and social system after the 1991 splitting of former Yugoslavia, the human and material devastation during 1991–1995 war and the slowest path of getting out of the 2008 economic crisis. One of the highest unemployment rates, especially among young people (45.5 %, 2014) (Eurostat, Unemployment Statistics) and the lowest expected employment rate in the EU for 2020 (63%) (Eurostat, Europe 2020 targets) make Croatia economically, socially, and politically vulnerable. In such context, activities related to creating new jobs are of the utmost importance and anyone's knowledge, skills, and commitment lost in this process is socially and politically unaccountable. Using this angle and aggregated Global Entrepreneurship Monitor (GEM) data from the 2003–2013 period, the chapter presents several gender patterns of businesses with growth potential in Croatia. Businesses with the highest growth potential in the GEM survey are defined by using three dimensions: (a) newness of the product—only if a product is new to all customers, (b) low exposure to competition—only if there are no other businesses offering the same product to the same target group of customers, and (c) newness of used technologies or procedures—only if required technologies or procedures for making this product are available less than a year.

Literature Review/Theoretical Background

Gender patterns of businesses with growth potential can be explored from many angles (e.g., theory of the firm, entrepreneurship, inclusion, macroeconomic aspects of using resources, etc.). In this research, some key theoretical concepts related to firm growth, entrepreneurship, innovation, and inclusion are discussed for framing the research questions (hypotheses).

The literature review confirms that researchers' interest is typically more focused on why and how businesses are created, and much less on why and how they grow. Despite the existence of many studies on enterprise growth stages, the study of a firm's growth patterns under the influence of internal and external factors is limited (Gupta et al. 2013).

If the gender aspect is added, even less research findings can be found. Research on business growth has been prominent in the last 50 years, while research on gender and business growth just in the last 20 years, and mostly in a number of specific countries.

On Firm Growth and Entrepreneurship

In the broadest sense, firm growth can be explained by improvements in some aspects of its vitality (competitiveness, profitability), not only at a point in time (e.g., 1 year), but also over a period of time. Since Penrose (1959, revised edition 2009) found that firm size results from its growth capability, and that growth results from the firm's effective and innovative managerial resources, many new insights emerged, and some old questions remained open. While there is an obvious consensus about the importance of business growth, especially due to the fact that fast-growing businesses are rare, but valuable to national economies because of their value-adding contribution (e.g., Shane and Venkataraman 2000; Delmar et al. 2003), much less is known about growth drivers and dynamics. For example, Bartelsman et al. (2005) analysis of post-entry performance of new firms in seven OECD countries found that about 20–40% of them fail within the first two years, and only 40–50% survive beyond the seventh year. Such results invite further research into factors enabling or preventing growth.

Research findings to date are far from reaching a consensus on why business growth is rare. A possible cause is that research approaches often analyze one or another dimension of business growth that produces many different indicators, and lose sight of the multi-faceted features of business growth, failing to build a holistic understanding of the business growth phenomenon.

Gibb (2000) made an interesting point about two parallel processes—increased interest in searching growth phenomena is matched by increased ignorance of them, leaving numerous "mythical concepts" and "myths" alive. Firm growth research led to some unchallenged assumptions about development processes that have been implicitly adopted and recycled by policy-makers. At the same time, it challenges social sciences researchers, especially in understanding the growth of business venturing.

In the same vein, Leitch et al. (2010), ten years later, argue that little is known about the growth phenomenon and that a lot of confusion and misunderstanding is still around. They suggest to move from a "change in amount" format to a "growth as a process", and also insist on inclusivity and pluralism in researching the growth phenomenon.

One such approach is the life cycle concept, which is not only widely used, but also criticized. The life cycle concept explicitly brings the time dimension in understanding the process of growth—a dimension that is often forgotten, despite the fact that each growth process always takes place along some timeline. The importance of the life cycle concept lies in understanding that changes in each development phase require a different set of entrepreneurial capabilities, organizational structure and innovation strategies. Using psychological findings which suggest that individual behavior is determined mostly by previous experience, Greiner (1972) argues that "the future of an organization may be less determined by outside forces than it is by the organization's history". Greiner brought thus individual behavior to the center of understanding the concept of a firm's life cycle. Greiner suggests that each firm experiences phases of evolution (prolonged period of growth without major organizational challenges) interrupted by crisis/phases of revolution (with substantial changes of organizational life).

Adizes (1979) connected the organizational life cycle concept with entrepreneurship, by emphasizing the need of re-configuration of resources (including self-commitment, vision, risk-taking capacity, etc.) and activities along the growth process, in order to capture emerging opportunities. By this, Adizes departs from the traditional life cycle concept based on programmatic stages and is in some way closer to more recent work of Levie and Lichtenstein (2010), who challenged the validity of the life cycle concept, especially on the grounds of not capturing the complexity of the business growth. They concluded that the modeling of growth stages has hit a dead end.

Levie and Lichtenstein (2010, 33) propose a dynamic states approach, which is based on a "network of beliefs, relationships, systems and structures that convert opportunity tension into tangible value for an organization's customers/clients, generating new resources that maintain the dynamic state." The ability to change the destiny of an organization by using available resources, and co-create opportunity is emphasized in several concepts grounded in systems theory, such as the view of a firm as an energy-conversion system (Slevin and Covin 1997), as properties of emerging organizations (Katz and Gartner 1988), as part of effectuation (Sarasvathy 2001), or generative emergence (Lichtenstein 2014).

Such approaches bring together different theoretical perspectives, like the resource-based perspective, the motivation perspective, the strategic adaptation perspective and the configuration perspective.

The literature provides insights into the empirical testing of some features of business growth discussed above. Kolvereid and Bullvag (1996) showed the existence of a relationship between entrepreneurs' growth intentions and actual firm growth, and concluded that growth intentions can predict actual growth. Storey (1994) identified three factors for growth: the entrepreneur, the firm, and the strategy, which adds to understanding that growth of small businesses is influenced by a complex set of interrelated factors.

Cooney (2012) finds broad agreement among scholars about the primary drivers of business growth, i.e., (1) motivation, (2) resources, and (3) market opportunities, and emphasizes the role of owner and his/her motivation. This view is supported by Orser (1997) who found that "those firms whose owners had stated five years previously that they wanted to grow the business were now more successful, while the majority of firms owned by entrepreneurs who did not prioritize growth had either not grown or had failed." (in Cooney 2012, 3).

Besides internal factors (such as intentions), the role of the entrepreneurial ecosystem in business growth has been recognized. Davidsson (1989) warned that a complicated regulatory system and an unfavorable tax system can reduce the willingness of small businesses to grow. Lumpkin and Dess (1996) made a major contribution to understanding the multidimensional feature of an entrepreneurial orientation construct (autonomy, innovativeness, proactiveness, risk-taking and competitive aggressiveness) and its relationship with the firm's performance, by adding environmental and organizational factors.

The lack of internationally comparable data about entrepreneurship contributed to the absence of insights into how much contextual differences influence the entrepreneurial capability of a country across the world. Building on a holistic approach, and trying to capture multi-faceted features of entrepreneurship, the Global Entrepreneurship Monitor (GEM) survey built a conceptual framework that assumes interactions between an entrepreneurial ecosystem and an individual (described by a set of attributes and perceptions of societal values) in the venturing process (identified in two stages: the first 42 months and after the first 42 months), as presented in Fig. 5.1. GEM collects such data on a yearly basis in around 70 countries which cover around 90% of the world's GDP (the collection of data started in 1999, so for many countries longitudinal data are available as well).

The GEM database is useful for checking if specific patterns of entrepreneurial activities can be recognized across different countries and different economies.

GEM special reports on high-growth entrepreneurship (Autio 2006; Autio 2007), then the joint report on high-impact

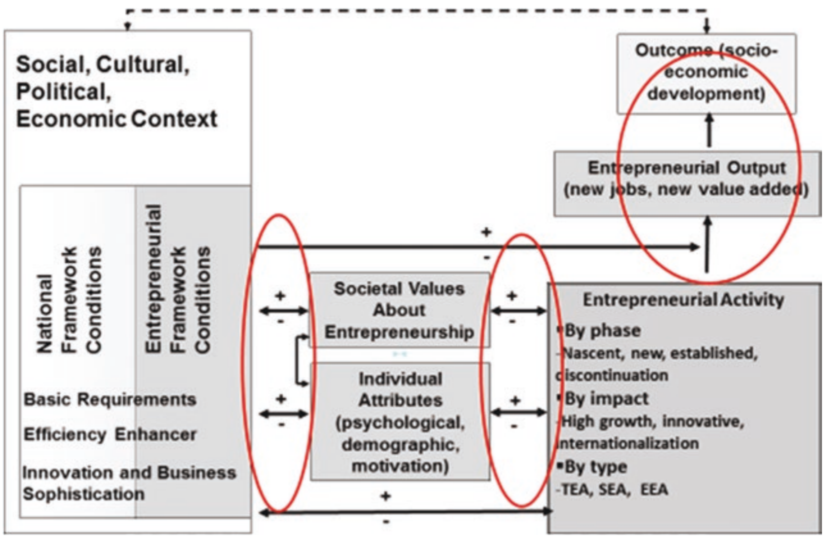

Fig. 5.1 The GEM Conceptual Framework. *Source* Kelley, et al. (2016), p. 12

entrepreneurship published with Endeavor (2011) and the report *Leveraging Entrepreneurial Ambition and Innovation: A Global Perspective on Entrepreneurship, Competitiveness and Development*, jointly developed and published with the World Economic Forum (2015) provide insights into multi-faceted aspects of business growth and provide some answers of why and how some businesses grow or not.

On Gender and Business Growth

The gender issue is approached more often from the human rights angle, and less from resource efficiency aspect.

Since 2006, the World Economic Forum has been producing the Global Gender Gap Index, which measures the gap between men and women in four categories (sub-indexes): Economic Participation and Opportunity, Educational Attainment, Health and Survival and Political Empowerment. In the discussion on gender patterns in business growth, some research indicated that the gap in educational attainment can be a limiting factor for women's involvement in business growth, but this hypothesis has been disproven. In general, gaps in health and educational attainment are almost closed (145 countries covered in the 2015 Report have closed almost 96% of the gap in health outcomes between women and men, and 95% of the gap in educational attainment). However, the gaps between women and men in economic participation and political empowerment are still very wide: only 59% of the economic outcomes gap and 23% of the political outcomes gap have been closed (Global Gender Gap Report 2015).

GEM is surveying, additionally to its regular annual survey, entrepreneurship from a gender perspective. GEM special reports on women's entrepreneurship were published for the years 2006 (Allen et al. 2007), 2007 (Allen et al. 2008), 2010 (Kelley et al. 2011), 2012 (Kelley et al. 2013), and 2015 (Kelley et al. 2015). The purpose of the GEM Women's reports is to learn about similarities and differences in the frequency and nature of women's entrepreneurship, compared to men, across various economies. Specifically, the reports provide information on female entrepreneurship rates and gender gaps in the following key areas:

- Participation in multiple phases of activity
- Characteristics and motivations of women entrepreneurs
- Societal attitudes about entrepreneurship
- Impact indicators

The GEM data confirm the existence of the gender economic outcomes gap, not only by measuring the intensity of entrepreneurial activities, but also the motivational aspect. Compared with men, women are less entrepreneurially active and their motivation for entrepreneurship is less based on opportunity recognition. Pines et al. (2010) showed that equality in entrepreneurial activities (measured by the percent of women entrepreneurs) is higher in countries where the general income per capita is small, and where women have no other option for making a living. It looks that poverty is more equalizing women and men in entrepreneurial activity than any other factor.

Gender-related difference in performance of business ventures (e.g., measured through export orientation, jobs creation, etc.) is also confirmed by GEM surveys, and is a topic of interest for researchers. Loscocco et al. (1991) researched why women generate lower sales volumes and derive less income than their male counterparts. They concluded that different characteristics of the owner and the small business, based on gender criteria, explain this gap in business performance. The smaller size of businesses owned by women is the major explanatory factor, followed by women's lack of experience and their concentration in the least profitable industries. Robichaud et al. (2010) researched the differences in motives to start a business among a sample of owners of recently created businesses across Canada and revealed a relationship between successful launches of a business and few characteristics of entrepreneurs, like level of education, skills, self-confidence, income and networking. Their conclusion was that if women lack (for different reasons) such characteristics, then their lower business performance can be explained.

Rosa et al. (1996) surveyed 600 Scottish and English small business owner-managers (300 women, 300 men). Their analysis suggests that the relationship between gender and small business performance is complex, and gender appears to be a significant determinant even after other key factors are controlled for. On the contrary, Johnsen and McMahon

(2005) found no consistent statistically significant differences in financial performance and business growth between female and male owner-managed businesses, if appropriate demographic and other relevant controlling influences are taken into account.

Tominc and Rebernik (2006) searched individual attributes of Slovenian entrepreneurs using gender criteria and found that women, on average, do not start their entrepreneurial ventures with lower expectations than men. This suggests that there is no inherent reason for women to be less effective than men during their entrepreneurial careers. It opens some other questions related to the structure and quality of business environment in which women and men function. Coleman and Robb (2014) analyzed access to capital by high-growth women-owned businesses for the US National Women's Business Council, and found that women-owned firms exceeded their own growth expectations in the period 2008–2011 (despite the fact that the women were less likely than men to expect rapid firm growth, defined by number of employees).

Fairlie and Robb (2009) surveyed the performance of female-owned businesses, compared to male-owned businesses, by using confidential data from the U.S. Census Bureau. They found that female-owned businesses are less successful than male-owned businesses because they have less start-up capital and less business human capital (less prior work experience in similar business and less prior experience in a family business). They also found that women business owners work fewer hours and may have different preferences for the goals of their business.

Few researchers make an explicit analysis of gender imbalance in entrepreneurial activity as an economic resource issue. Tominc and Rebernik (2006, 50) recognize that "women represent an unexploited resource for entrepreneurship." This brings back the issue of the gender economic performance gap and the need to learn more about its causes.

The Case of Croatia

Croatia is a small country with a 4, 2 million population (2014), with the tendency of rapid aging and depopulation. It has a GDP per capita of USD 13,494 (2014) and an SME's contribution to GDP of 54%

(2014). The Croatian economy is in transition from an efficiency-driven to an innovation-driven development phase, according to the classification used by the World Economic Forum.

Before the global financial crisis of 2008–2009, the Croatian economy grew at 4–5% annually, but the effects of the crisis locked Croatia in six years of recession. Some very weak signs of slow improvement came only in 2015.

Croatia experienced two mega changes at the beginning of 1990s. First, after the splitting of former Yugoslavia in 1991, changes caused by the introduction of a parliamentary democracy and a full market economy required new knowledge and skills in running the country and businesses, as well as a new institutional infrastructure. Second, from 1991 to1995, Croatia had the war, and only at the beginning of 1998 all occupied territories which were under UN control were re-integrated back to Croatia. Those two mega changes were accompanied by staggering problems of a very corrupt privatization process, huge war devastation of human, physical and economic resources, slow process of institutional restructuring needed to serve new political (democratic) and economic system (market economy), and lack of national consensus on strategic priorities for the country. Also, in order to build a new institutional structure, the education system was challenged, and did not respond fast enough to the changing needs of the society.

The intensity of changes can be illustrated by the changed structure of employment in Croatia: employment in small enterprises doubled, while employment in medium and large enterprises halved in 2000 relative to 1990, but the education sector stayed "business as usual", not reacting to such change.

International surveys on competitiveness (World Economic Forum), entrepreneurship (Global Entrepreneurship Monitor), and innovation (Innovation Union Scoreboards) confirm each other in regard to low innovativeness, low share of growing businesses, and persisting gap in entrepreneurial activities using gender criteria.

Croatia's competitiveness profile showed deterioration from 2002 to 2015, when Croatia slipped from the 50s to the 70s rank and has kept this position unchanged for several years. Inefficient government bureaucracy, policy instability, tax rates, access to finance, and restrictive labor regulations have been constantly identified as the most problematic factors (Schwab 2015).

According to the 2015 Innovation Union Scoreboard (EU 2015), Croatia is a moderate innovator. Innovation performance improved until 2011 and then declined, slightly recovering in 2013. Croatia is performing below the EU average in most dimensions, but is above the EU average in Human resources (due to the educational level). The weakest performing dimension is the quality of research systems; also all dimensions related to SMEs (product/process innovations, marketing/organizational innovations, collaboration of innovative SMEs) are below the EU average.

The entrepreneurship capability of Croatia has been regularly monitored since 2002 through participation in the GEM survey. It positions Croatia as a country in transition from an efficiency-driven economy to an innovation-driven economy, with a very low motivational index (ratio between new ventures started out of recognized opportunities and those started out of necessity, i.e., because of the lack of other choices). A value of the index below 1 indicates more new ventures started out of the necessity. Croatia's motivational index of only 1.0 in 2015 is lower than the average value of motivational index in efficiency-driven economies (2.0), and is even lower than in factor-driven economies (1.5). Innovation-driven economies have a motivational index at the level of 3.4, with the highest values for Switzerland (6.5) and Norway (6.3) (Kelley et al. 2016).

Another feature of Croatia's entrepreneurship capacity is the low innovation level (measured by the percentage of new ventures with new products to all or without strong competition). The average value of this indicator for efficiency-driven economies is 24%, and for Croatia it is 16.9%, which is even lower than the average of this indicator in factor-driven economies (Kelley et al. 2016).

The third important feature, relevant to this survey, is the gender perspective of entrepreneurial activities: in Croatia only 5.7% of women are entrepreneurially active vs. 13.0% of women in efficiency-driven economies, and even 46.1% of entrepreneurially active women started their venture out of the necessity vs. 33% in efficiency-driven economies (Kelley et al. 2016).

Additionally, Kelley et al. (2014) indicated that Croatia has a deficit of innovative female businesses, compared to the average of efficiency-driven economies in Europe. More than in the European efficiency-driven economies, female entrepreneurs in Croatia are in business services sector, they are more ambitious, measured by the indicator of expected job creation (6 and more jobs in the next 5 years), and they are more oriented toward international markets.

At the same time, GEM survey on gender aspects of entrepreneurial activity warned that Croatia is suffering from a low perception of opportunities among women and less networking (knowing an entrepreneur) than it is characteristic for European efficiency-driven economies.

From the regional perspective of the Danube region (Austria, Bosnia and Herzegovina, Croatia, Czech Republic, Germany, Hungary, Slovakia, Slovenia, and Romania), Croatia shows much less appreciation for successful entrepreneurs, and there are also less perceived opportunities comparing with the average for the Danube region (Tominc et al. 2015). For this analysis, GEM data for 2013 were used (except for Austria, for which 2012 GEM data were available).

Since entrepreneurial activity is happening in an entrepreneurial ecosystem, it is important to know how supportive or hindering the system is. Figure 5.2 provides a comparison of the quality of the different

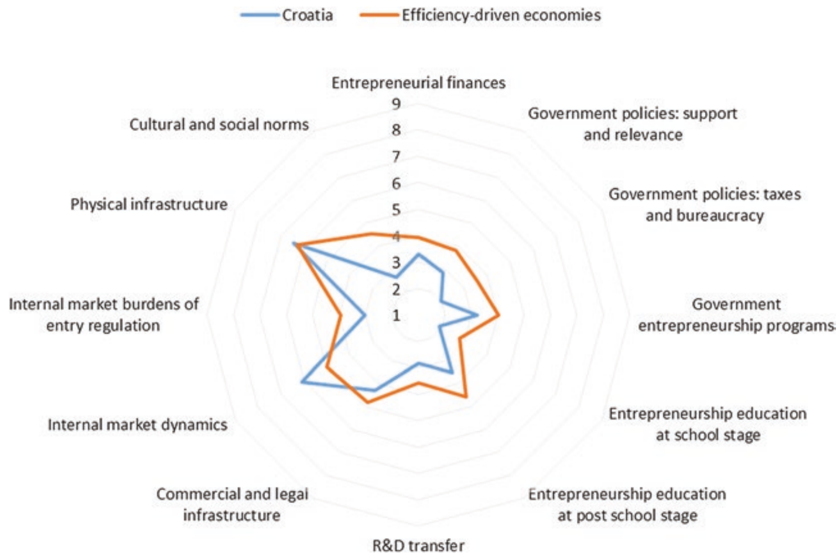

Fig. 5.2 Expert rating of the Entrepreneurial Ecosystem, 2015. *1*: highly insufficient, *9*: highly sufficient. *Source* GEM database, 2016, Croatia GEM team, CEPOR

dimensions of Croatian entrepreneurial ecosystem with the average of countries in the same development phase (efficiency-driven economies), involved in the GEM survey.

Experts' evaluation of two public policies that are relevant for this survey (women's support to business start-ups, attention to high growth) and interest of businesses in innovation (on a scale of 1—lowest to 5—highest), provide an additional insight into the entrepreneurial ecosystem of Croatia (GEM database, Croatia GEM team):

- Women's support to business start-up: in the 2002–2013 period average scores for Croatia grew from 2.71 to 3.01, while in countries like Island, Finland and Norway the scores were above 4.
- Attention to high growth: in the 2005–2013 period, average scores for Croatia grew from 2.52 to 2.69, and almost in all these years Ireland had a score above 4.
- Interest in innovation, from the perspective of the business sector: in the 2007–2013 period average scores for Croatia have oscillated between 2.5 and 2.78, while in countries like Singapore, UAE, Island, and Taiwan the scores were above 4 or close to 4.

Entrepreneurial activity in Croatia is performed in the described context and it provides the broadest framework in which gender patterns of businesses with growth potential will be analyzed.

Conceptual Framework and Hypothesis

It is well documented in the literature that the growth potential of businesses is based on their innovative capacity (in offering new products/services, using new technologies, penetrating on new markets), which is also related to the owner's motivation, as discussed in the literature review section. Using GEM data for Croatia, Šarlija and Pfeifer (2015, 1) found that "innovative orientations vary with personnel, firm, meso and macro level variables, and between different stages in entrepreneurship process.

Significant predictors are the occupation of the entrepreneurs, the size of the firm and export aspirations for both early-stage and established entrepreneurs. In addition, fear of failure, expecting to start a new business, and seeing an entrepreneurial career as a desirable choice are predictors of the innovative orientation among early-stage entrepreneurs."

The research presented in this chapter intends to determine if gender patterns can be identified among cohorts of innovative and non-innovative entrepreneurs.

The identification of research hypotheses relies on a fragment of the GEM conceptual framework (Fig. 5.3) and its extension showing phases of business venturing (early stage—up to 42 months, and established—after 42 months) and the clusters of variables assumed to have an influence on that (Fig. 5.4).

Additionally, the analysis will be focused on differences between early-stage businesses (up to 42 months at the moment of surveys) and established businesses (older than 42 months), based on personal demographics and attributes, firm demographics and impact (business growth, innovation, internationalization) using gender lenses. By differentiating between early-stage businesses and

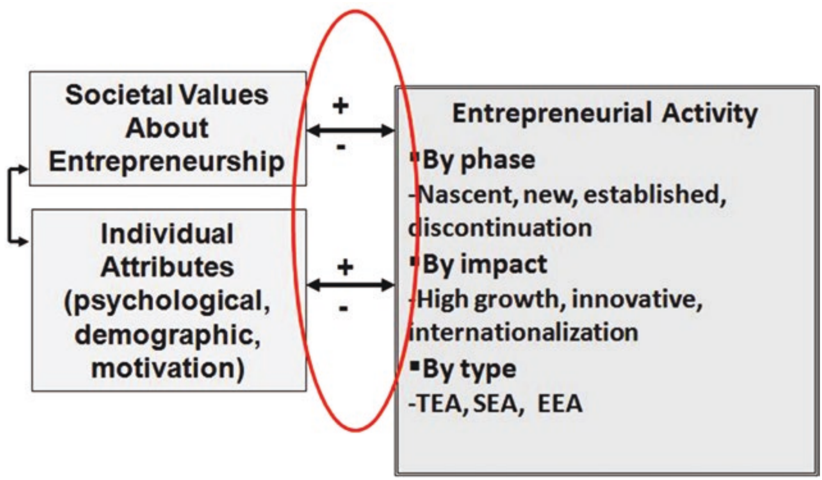

Fig. 5.3 GEM conceptual framework (fragment used for testing assumed relationships)

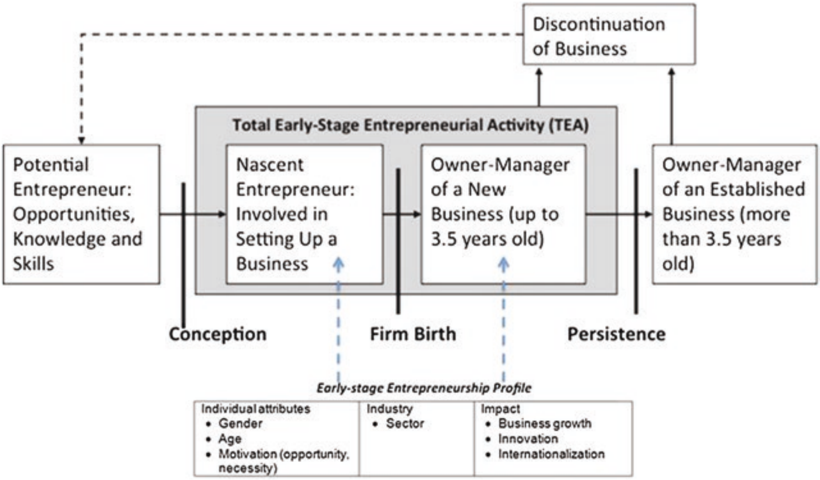

Fig. 5.4 Model of Business Phases and Entrepreneurship Characteristics as presented in GEM. *Source* Kelley et al. (2016), p. 13

established businesses, this research is testing the viability of the approach suggested by Levie and Lichtenstein (2010), who argue that the traditional life cycle concept should be replaced by a dynamic states approach in which a differentiated network of beliefs of individuals play an important role, as discussed in the literature review section.

The assumed differences between "innovative" and "non-innovative" women and men will be tested through the following research hypotheses:

H1: There is a significant difference between innovative women and innovative men, based on independent variables clustered as personal demographics, personal attributes and societal values, firm demographics and firm innovation strategies.

H2: There is a significant difference between innovative and non-innovative women, based on independent variables clustered as personal demographics, personal attributes and societal values, firm demographics and firm innovation strategies.

H3: There is a significant difference between innovative and non-innovative men, based on independent variables clustered as personal demographics, personal attributes and societal values, firm demographics, and firm innovation strategies.

Innovative individuals represent the dependent variable, described by gender, newness of products, newness of technology and exposure to competition. All other variables are independent ones.

Data, Variables, Sample, and Method

Data Sources and Variables Used in Testing the Hypotheses

In order to identify the gender patterns of businesses with growth potential in Croatia, the GEM data set for Croatia was used, which is collected by using several instruments. For the purpose of this analysis, data collected through the Adult Population Survey (APS) are used. This instrument is a standardized questionnaire, covering a very broad set of data on entrepreneurial attributes and activities of sampled individuals.

By using data from APS questionnaire (detailed description of variables is presented in the Appendix—Table A5.1), four clusters of variables were built:

(a) Personal demographics (gender, age, household size, work status, income level, education)
(b) Personal attributes and societal values (knowing an entrepreneur, perceived opportunities for starting a business, perceived capabilities for starting a business, fear of failure, intentions to start a business; societal values toward entrepreneurship: desirable career choice, high level of status, media attention to successful new businesses)
(c) Firm demographics (ownership, management, number of employees)
(d) Firm innovation strategy (newness of products, newness of technology, exposure to competitors, internationalization, expected job creation)

Since the GEM survey is conducted on a sample of a minimum size of 2000 randomly selected adults, based on criteria of age and gender, a one-year data set would not be sufficient to recognize gender patterns

Table A5.1 List of variables and GEM APS-related questions

Code and variable category		
Personal demographics		
Gender	Female Male	What is your gender?
Age		What is your age (in years)?
Hhsize		How many members make up your permanent household, including you?
Gemwork3	Working Not working Student/Retired	Working status?
Gemhhinc	Lower Middle Upper	Which of these ranges best describes the total annual income of all the members of your household, including your income, as one combined figure?
Gemoccu	Full/Part time Part Retired, disabled Homemaker Student Not working Self-employed	What of the following describes your current employment status?
Gemeduc	Some secondary Secondary Post-secondary Graduate	What is the highest level of education you have completed?
Personal attributes and societal values		
Knowent	No Yes	Do you know someone personally who started a business in the past 2 years?
Opport	No Yes	In the next six months, will there be good opportunities for starting a business in the area where you live?
Suskill	No Yes	Do you have the knowledge, skill and experience required to start a new business?
Fearfail	No Yes	Would fear of failure prevent you from starting a business?
Futsup	No Yes	Are you, alone or with others, expecting to start a new business, including any type of self-employment, within the next three years?
Nbgoodc	No Yes	In my country, most people consider starting a new business a desirable career choice.

(continued)

Table A5.1 (continued)

Code and variable category		
Nbstatus	No Yes	In my country, those successful at starting a new business have a high level of status and respect.
Nbmedia	No Yes	In my country, you will often see stories in the public media about successful new businesses.
Sureason/ Omreason	Opportunity No better choice Both Have a job but seek better Other	Are you involved in this start-up to take advantage of a business opportunity or because you have no better choices for work?
Firm demographics		
Suowners		How many people, including yourself, will own this new business?
Omnowners		How many people, including yourself, both own and manage this business?
Sunowjob/ Omnowjob		Not counting the owners, how many people are currently working for this business?
Firm innovation strategy		
Sunewcst/ Omnewcst	All Some None	Will all, some, or none of your potential customers consider this product or service new and unfamiliar?
Sunewtec/ Omnewtec	Less than a year Between one to five years Longer than five years	How long have the technologies or procedures required for this product or service been available?
Sucompet/ Omcompet	Many Few No	Right now, are there many, few, or no other businesses offering the same products or services to your potential customers?
Suexport/omnexport	More than 90% 76–90% 51–75% 26–50% 11–25% 10% or less None	What proportion of your customers will normally live outside the country?
Suyr5job/omxt5job		Not counting owners, how many people will be working for this business five years from now?

of businesses with growth potential. Therefore, the data set of selected items from the APS questionnaire was built for the period 2003–2013, which provided adequate stock of data to test the hypotheses.

Sample

In Croatia, the GEM survey is conducted on the sample of 2000 adults, 18–64 years of age, from 2002. The sample provides insights into entrepreneurial attributes and activities of individuals engaged in (a) early-stage entrepreneurial ventures (an adult who starts, manages and owns, fully or partially a business not older than 42 months) and (b) established ventures (an adult who manages and owns, fully or partially a business older than 42 months). In order to assess the gender patterns of businesses with growth potential, an additional structuring of the sample was implemented, using the gender and the innovative capacity of entrepreneurs. The whole structure of the sample is presented in Table 5.1.

Method

Building insights into the gender patterns of businesses with growth potential in Croatia, and testing the identified hypotheses relied on descriptive statistics, t test and Chi-square test. The t test was used to test differences between two means and the Chi-square test was used to test dependence between categorical variables (Sheskin 2004).

Table 5.1 Sample, based on APS Croatia 2003–2013 aggregated data set

		Early-stage entrepreneurs (ventures not older than 42 months)		Established entrepreneurs (ventures older than 42 months)	
		Number	%	Number	%
Innovative entrepreneurs	Women	137	10.3	69	10.1
	Men	375	28.2	140	20.6
Non-innovative entrepreneurs	Women	256	19.2	164	24.2
	Men	564	42.3	306	45.1
Total		1332	100	679	100

Findings

The applied analysis confirmed all three hypotheses by identifying significant differences between some variables, as it is shown in Table A5.2, A5.3, Table A5.4, A5.5, and Table A5.6, A5.7 (in the appendix). In summary, there are distinctive patterns of businesses with growth potential:

- depending on gender
- depending on the stage of business venturing,
- depending on the criteria of innovativeness in the cohorts of women and men (innovative and non-innovative)

Table A5.2 Significant differentiators of innovative women and innovative men, across the development phases of businesses, Croatia

Variable		Early stage (less than 42-month-old ventures)	Established ventures (more than 42-month-old ventures)
Personal demographics	Age	***	*
	Hhsize	***	*
	Gemwork3		*
	Gemhhinc		
	Gemoccu		
	Gemeduc		
Personal attributes and social values	Knowent	**	***
	Opport		***
	Suskill		*
	Fearfail		
	Futsup		
	Nbgoodc		
	Nbstatus		
	Nbmedia		
	Sureason/Omreason		
Firm demographics	SuownersOmnowners		**
	Sunowjob/Omnowjob		
Firm innovation strategy	Suexport/omnexport	***	*
	Suyr5job/omxt5job	*	

Statistical significance *** 1% ** 5% * 10%

Table A5.3 Innovative women vs. innovative men: values of statistically significant variables—in percentage of total value for a respective variable or average number

		Early-stage entrepreneurs (ventures not older than 42 months)		Established entrepreneurs (ventures older than 42 months)	
		Women	Men	Women	Men
Household size (Hhsize)	Average number			3..4	3.8
Household annual income (gemhhinc)	Upper	44.4	56.8	42.4	57.3
Work status (gemoccu)	Full or part time	50.5	46.1	41.1	62.2
	Self-employed	22.3	30.0		
Know an entrepreneur (knowent)	Yes			25.7	74.3
Have a knowledge to start a business (suskill)	Yes			84.9	99.3
High societal status (nbstatus)	No			67.2	52.2
Reason to be involved in the business (Sureason/Omreason)	Take the advantage of opportunity	40.4	54.1		
	No better choice for work	42.9	32.1		
Number of employees (Sunowjob/Omnowjob)	Average number			3.1	13.9
Export orientation (Sureason/Omreason)	0%	32.6	30.7		
	26–75%	11.8	22.9		
	75% +	11.5	16.1		
New jobs in 5 years (Suyr5job/omxt5job)	Average number	12.3	34.8	4.8	20.1

Table A5.4 Significant differentiators of innovative women and non-innovative women, across the development phases of businesses

Variable		Early stage (less than 42-month-old ventures)	Established ventures (more than 42-month-old ventures)
Personal demographics	Age		*
	Hhsize		*
	Gemwork3		*
	Gemhhinc		
	Gemoccu		
	Gemeduc		
Personal attributes and social values	Knowent	**	
	Opport	*	
	Suskill	**	
	Fearfail		
	Futsup		
	Nbgoodc		
	Nbstatus		
	Nbmedia		
	Sureason/Omreason		
Firm demographics	Suowners/Omnowners		*
	Sunowjob/Omnowjob		
Firm innovation strategy	Suexport/omnexport		**
	Suyr5job/omxt5job		*

Statistical significance *** 1% ** 5% * 10%

Table A5.5 Non-innovative women vs. innovative women: values of statistically significant variables—in percentage of total value for a respective variable or average number

		Early-stage entrepreneurs (ventures not older than 42 months)		Established entrepreneurs (ventures older than 42 months)	
		Women non-innovative	Women innovative	Women non-innovative	Women innovative
Household size (Hhsize)	Average number			3.8	3.4
Work status (gemoccu)	Full or part time			29.2	35.0
	Self-employed			57.4	41.1
Educational attainment (Gemeduc)	Some secondary			23.1	32.9
	Secondary			60.7	43.2
	Post-secondary			36.9	24.0
Know an entrepreneur (knowent)	Yes	59.2	71.3		
Seeing opportunity in the next 6 months (Opport)	Yes	39.2	48.4		
Fear of failure (Fearfail)	No	66.3	78.0		
Number of employees (Sunowjob/Omnowjob)	Average number			9,4	3,1
Export orientation (Sureason/Omreason)	0%			39.2	42.2
	26–75%			13.6	10.1
	75% +			7.0	9.1
New jobs in 5 years (Suyr5job/omxt5job)	Average number			11.9	4.8

Table A5.6 Significant differentiators of innovative men and non-innovative men, across the development phases of businesses

Variable		Early stage (less than 42-month-old ventures)	Established ventures (more than 42-month-old ventures)
Personal demographics	Age	*	*
	Hhsize	*	
	Gemwork3		
	Gemhhinc		
	Gemoccu		
	Gemeduc		
Personal attributes and social values	Knowent	*	***
	Opport	**	**
	Suskill	*	
	Fearfail	*	
	Futsup	*	
	Nbgoodc	*	
	Nbstatus	*	
	Nbmedia		
	Sureason/Omreason		
Firm demographics	Suowners/Omnowners	**	
	Sunowjob/Omnowjob	**	
Firm innovation strategy	Suexport/omnexport	***	***
	Suyr5job/omxt5job	*	

Statistical significance *** 1% ** 5% * 10%

H1: There is a significant difference between ***innovative women and innovative men****, based on independent variables clustered as personal demographics, personal attributes and societal values, firm demographics and firm innovation strategies—CONFIRMED.*

Distinctive differences between innovative men and innovative women in both stages of venturing (early stage and established) were identified.

Early-Stage Venturing (Innovative Women and Innovative Men)

For this stage of venturing, the difference between innovative women and men stems from the following variables (Fig. 5.5):

- ***household income***—entrepreneurially active innovative men come from households with higher household income: 57.5% men belongs to the upper 33 percentile vs. 44.4 % innovative women
- ***working status***—there is a higher share of men with self-employed status than women (30.0 vs. 22.3%); and higher share of full-time status among women than among men (50.5 vs. 46.1%)
- ***reason for venturing***—higher share of men starting a business because of taking the advantage of a recognized opportunity than women (54.1 vs. 40.4%). There are more women who started a business because they did not have a better choice for work (42.9 vs. 32.1%)
- ***export orientation***—despite the fact that both women and men are at the same level of not exporting, there is an important difference among those who are exporting. Men export more (39% of them export 26% or more of annual sales), while only 23.3% of women do the same.
- ***expected new jobs in 5 years***—men have much more ambitious expectations for creating new jobs compared to women (34.8 vs. 12.3%).

Table A5.7 Non-innovative men vs. innovative men: values of statistically significant variables—in percentage of total value for a respective variable or average number

		Early-stage entrepreneurs (ventures not older than 42 months)		Established entrepreneurs (ventures older than 42 months)	
		Men non-innovative	Men innovative	Men non-innovative	Men innovative
Age	Average number	36.9	36.5	45.5	43.7
Household annual income (gemhhinc)	Upper	50.5	56.8		
Educational attainment (Gemeduc)	Some secondary	33.2	32.9		
	Secondary	42.0	35.7		
	Post-secondary	24.8	31.4		
Know an entrepreneur (knowent)	Yes	67.5	72.5		
Seeing opportunity in the next 6 months (Opport)	Yes	47.4	54.8		
Have a knowledge to start a business (suskill)	Yes			92.9	99.3
Expect to start a business in the next 3 years (Futsup)	Yes	47.6	53.2		

(continued)

Table A5.7 Continued

		Early-stage entrepreneurs (ventures not older than 42 months)		Established entrepreneurs (ventures older than 42 months)	
		Men non-innovative	Men innovative	Men non-innovative	Men innovative
Starting a business is a good career choice (ngoodc)	Yes	62.4	68.6		
High societal status (nbstatus)	Yes	41.4	47.5	36.0	48.0
Media celebrates successful businesses (nbmedia)	Yes	51.2	45.4		
Reason to be involved in the business (Sureason/Omreason)	Take the advantage of opportunity	44.6	54.1		
	No better choice for work	37.1	32.1		
How many people own and manage this business (Suowners/Omnowners)		2.5	1.8		
Number of employees (Sunowjob/Omnowjob)	Average number	8.4	37,6		
Export orientation (Sureason/Omreason)	0%	31.5	30.7	29.6	38.3
	26–75%	17.8	22.9	13.8	22.5
	75% +	11.0	16.1	6.5	6.5
New jobs in 5 years (Suyr5job/omxt5job)	Average number	14.1	34.8		

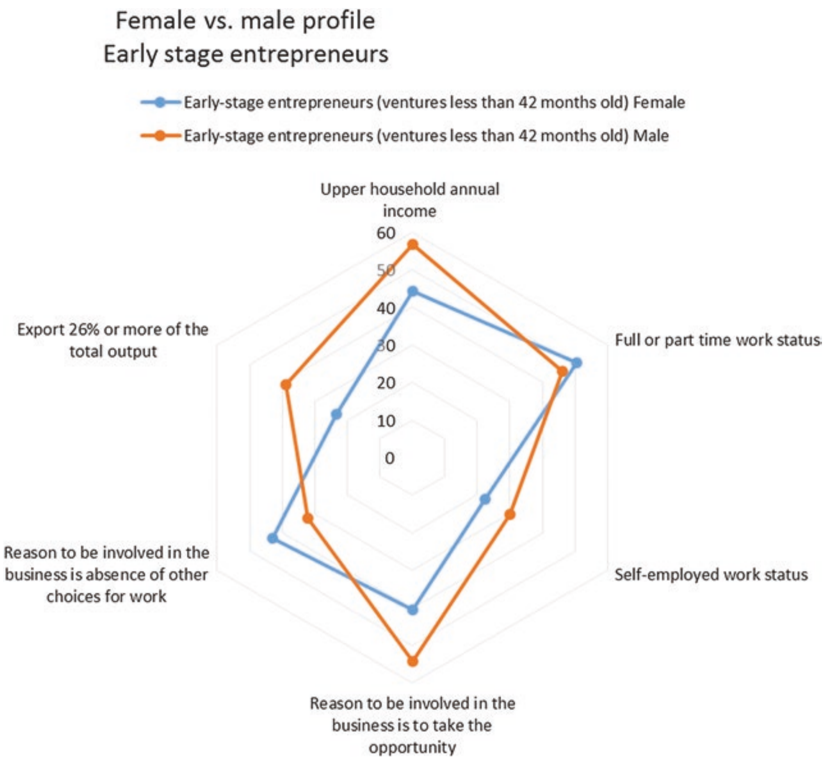

Fig. 5.5 Gender pattern of businesses with growth potential—early-stage entrepreneurs, Croatia

Established Venturing (Innovative Women and Innovative Men)

For this stage of venturing, the difference between innovative women and men stems from more variables than in the case of early-stage venturing. Only three variables are the same as in the case of early-stage venturing (household income, working status and expectations about new jobs in the next 5 years). It indicates that the stage of venturing plays a role in activating a differentiated set of influential variables, as it was also argued by Levie and Lichtenstein (2010) in their concept of dynamic states of venturing. The difference between innovative men and innovative women emerges from the following variables (Fig. 5.6):

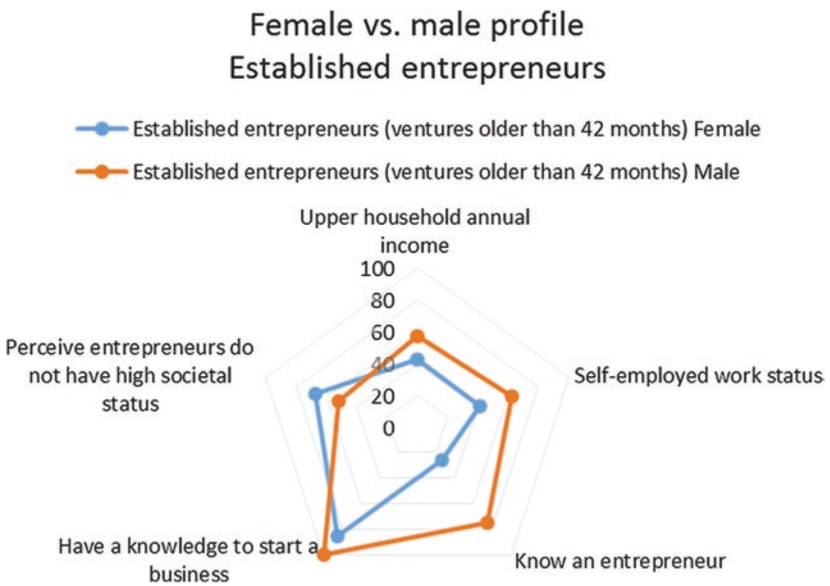

Fig. 5.6 Gender pattern of businesses with growth potential—established entrepreneurs, Croatia

- ***household size***—innovative men come from a bigger household than women (3.8 members vs. 3.4 members)
- ***household income***—as in the case of early-stage venturing, innovative men come from households with higher household income: 57.3% men belongs to upper 33 percentile vs. 42.4% innovative women
- ***working status***—higher share of men with self-employed status than among women (62.20 vs. 41.1%)
- ***know an entrepreneur*** (as an indicator of capability of networking and using other people's experience)—three times more men are better connected/networked than women (74 vs. 25.7%)
- ***perception about own knowledge and skills***—needed for running a business is quite high among both groups, but men are much more self-confident (99.3 vs. 84.9%)
- ***societal status of successful entrepreneurs***—more than half of both groups think that successful entrepreneurs do not have high societal status, but women are more critical (52.2 of men vs. 67.2 of women).

- ***number of employees***—innovative women have much smaller businesses than men (3.1 employees vs. 13.9 employees)
- ***expected new jobs in 5 years***—innovative men have five times higher expectations about creating new jobs in the next 5 years than women (20.1 vs. 4.8%).

Analyzing both groups together, it looks like women are more cautious/conservative in developing own businesses (smaller businesses according to the number of employees, expected creation of new jobs). Both groups have similar educational background and both groups are of the same average age (36.5), but a strong differentiator is obviously the networking capacity (know other entrepreneur). It could be an additional challenge to investigate why innovative women appear to be less ambitious than their male counterparts. Is it because of the industry in which they are entrepreneurially active, or because they work less hours, as it was identified by Fairlie and Robb (2009)

After confirming the first hypothesis of differences in the gender patterns of businesses with growth potential, it was an additional challenge to see if there are significant differentiators between innovative and non-innovative members inside each cohort (women, men).

H2: There is a significant difference between ***innovative and non-innovative women****, based on independent variables clustered as personal demographics, personal attributes and societal values, firm demographics and firm innovation strategies—CONFIRMED.*

Early-Stage Venturing (Non-Innovative Women and Innovative Women)

Innovative women are better connected/networked than non-innovative women (71.3 vs. 59.2% know an entrepreneur), they see more often opportunities than non-innovative women (48.4 vs. 39.2%) and more of them express fear of failure than non-innovative women (78.0 vs. 66.3%). Innovative women are involved in riskier venturing, which could be an explanation for such a result, but it requires more research.

Established Venturing (Non-Innovative Women and Innovative Women)

Values of differentiators between non-innovative and innovative women who are involved in established venturing are surprising and against some intuitive expectations, which requires additional research. As it is visible from Table A5.5 (Appendix), non-innovative entrepreneurs are better educated, in average they employ three times more people in their firms (9.4 vs. 3.1 in innovative firms), and they expect to create twice more jobs in the next 5 years (11.9 vs. 4.8 in innovative firms). Both non-innovative and innovative women have the same level of export activities.

H3: There is a significant difference between ***innovative and non-innovative men,*** *based on independent variables clustered as personal demographics, personal attributes and societal values, firm demographics, and firm innovation strategies—CONFIRMED.*

Early-Stage Venturing (Non-Innovative Men and Innovative Men)

Innovative men are better connected/networked than non-innovative men (72.5 vs. 67.5% know an entrepreneur), they see more often opportunities than non-innovative men (54.8 vs. 47.4%) and most of them expect to start a business in the next 3 years (53.2 vs. 47.6%). More innovative men than non-innovative men think that being an entrepreneur is a good career choice (68.6 vs. 62.4%) and that they have high societal status (47.5 vs. 41.4%). Innovative men more often start a business because of opportunity recognition (54.1 vs. 44.6%) and more non-innovative men decide upon venturing because they did not have a better choice (37.1 vs. 32.1%). Businesses owned by innovative men export more than non-innovative business owners (39 vs. 28.8%), but the biggest difference is in the size of present business by number of employees (37.6 in businesses owned by innovative entrepreneurs and 8.4 in businesses owned by non-innovative men). Innovative men also expect to create 2.5 times more jobs in the next 5 years than non-innovative men.

Established Venturing (Non-Innovative Men and Innovative Men)

There are much less differentiators among non-innovative and innovative men involved in established businesses. Innovative men are very confident and own knowledge and skills needed to start a business (99.3% of surveyed sample of innovative men think so vs. 92.9% of non-innovative men). Innovative men appreciate high societal status for successful entrepreneurs (48%), while less number of non-innovative men think so (36%). More innovative men (29%) have higher share of their sales from exporting (more than 26%) than non-innovative men (20.3%).

Discussion and Conclusions

The findings presented above confirmed all three hypothesis and enabled conclusion about differentiated gender patterns of businesses with growth potential in Croatia, both for the early-stage businesses and established businesses, as presented in Figs. 5.5 and 5.6.

These findings contribute to verifying expected relationships between personal demographics, personal attributes and societal values, firm demographics and business innovation strategies, using two criteria by which the dependent variable (innovative vs. non-innovative entrepreneur) is defined, i.e., gender and intensity of innovative performance (newness of product, newness of technology and no many competitors). The survey also confirmed the importance of understanding the motivational aspects of an individual in venturing process, in both its phases (early stage and established).

Literature review revealed that the multi-faceted features of firm growth are too often reduced to the size of the firm, which prevented deeper insights into the varieties of factors contributing to growth. The analysis developed in this survey started with the definition of firm growth as based on the innovativeness capacity of a firm (measured by newness of products, intensity of exposure to competitors and newness of implemented technology) which is looked at through gender lenses.

The survey confirmed the multi-faceted features of firm growth because it identified a portfolio of influencers, not a single one. Also, the statistical analysis revealed that the portfolio of influencers differs depending on the gender and the phase of the venturing process.

The gender-sensitive influencers identified in this study are in line with several other studies, such as Loscocco et al. (1991), Rosa et al. (1996), or Fairlie and Robb (2009). The majority of identified influencers (motivation/reason to start a venture, expectations about the growth of venture, etc.) are related to individual behavior, which is the basis for understanding the life cycle concept of a firm or firm's growth, as Greiner (1972) argued, or Cooney (2012) who emphasized the role of owner and his motivation.

The reason for venturing (recognized opportunity or no other choices for work) is a very strong influencer for building innovative businesses, among innovative women and innovative men in early stage of business activity (using GEM criteria, up to 42 months). In later phases of venturing (businesses older than 42 months) the reason for venturing is no longer a strong influencer, but networking capacity, perceptions about personal capabilities (knowledge and skills) and perception how entrepreneurs are seen in the society (societal status) become strong influencers. In both phases of business venturing, identified influencers differ because of gender (women start a venture more often out of lack of other work choices than men, women have lower capacity for networking, women are more critical than men on how the society praises successful entrepreneurs). The only influencer which is gender free is the perception about own capabilities. Combining this finding with the one reported by Tominc and Rebernik (2006) that women do not start their entrepreneurial ventures with lower expectations than men is challenging to explore further what makes women's ventures smaller in size (number of employees).

Identified influencers as export orientation (in the early stage of venturing) and expectations related to job creation (in both phases of venturing) confirm that firm strategy plays an important role in strengthening the growth potential of businesses, jointly with the entrepreneur (motivation) and the firm (size and structure), as it was recognized by Storey (1994).

Differences in portfolios of influencing factors related to the different phases of venturing confirm Adizes's (1979) conclusion about the need for re-configuration of resources (including individual attributes) and activities along the growth process. The same finding is also in line with Levie and Lichtenstein's (2010) dynamic states approach which requests a changed network of beliefs, relationships, systems, and structures to convert opportunities into ventures.

Adding these findings to what is already known about the development context of Croatia (high unemployment, the lowest employment rate in the European Union—63% expected for 2020 vs. 75% for the EU average) confirms that the overall low innovation capacity of the Croatian economy and differences in gender patterns of innovativeness contribute to economic and social vulnerability of Croatia. In order to change this situation, it is necessary to look at growing businesses from the gender perspective as a part of value adding chain in building sustainable competitiveness of a country. New job creation is a result of higher competitiveness, and higher competitiveness depends on continuous innovativeness (in products, processes, business models, markets, etc.). Innovativeness is the result of human activity; therefore, everyone is invited to participate in this process. The gender differences identified in building the innovative capacity of Croatian economy is a call for researchers to investigate further to which extent this gender gap is related to the entrepreneurship ecosystem. Otherwise, women will remain "unexploited resources for entrepreneurship" (Tominc and Rebernik 2006).

The analysis developed in this study contributed to answering many questions, but as research always does, many new questions emerged. The differences in the cohort of women, between innovative and non-innovative established entrepreneurs are surprising, because non-innovative women appear to be more entrepreneurial (they export more, they expect to create more jobs, etc.). This requires additional, in-depth research. Other questions also emerge—are women less ambitious than men (looking at the expected job creation, yes; looking at exporting, yes), but those findings do not give insights into how an entrepreneurial ecosystem interferes with motivational differences between women and men. Existing business models do not sufficiently consider the gender dimension, and an entrepreneurial ecosystem should also take more into account the different life agendas of women and men. Entrepreneurial ecosystems that prevent women to participate in these activities equally to men have to be identified and re-designed. Despite the fact that GEM is collecting data on individuals (through Adult Population Survey) and on entrepreneurial ecosystem (through National Expert Survey) those two databases are not sufficiently used for detecting types and strengths of their interactions. Those questions are challenges for further research.

The aim of this analysis was to identify statistically relevant influencers in understanding gender-sensitive patterns of innovativeness in Croatian economy. All three hypotheses were confirmed, and that provides a good start to work on identifying their predicting capacity. As Kolvereid and Bullvag (1996) concluded that growth intentions can predict actual growth, further research could check if predicting the growth potential by using intentions or some other identified influencers are gender-free.

In the meantime, policy-makers in Croatia can use these gender patterns findings in businesses with growth potential and design more policy instruments and programs for innovative entrepreneurs. Unemployment issues, low competitiveness and low employment levels can be challenged by an increasing share of businesses with growth potential. It will take time to have an impact on the economic situation, but without it, it will never happen.

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Appendix

See Tables A5.1, A5.2, A5.3, A5.4, A5.5, A5.6 and A5.7.

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6

Gender-Sensitive Business Counselling: Changing the Gendered Pattern and Understanding of Entrepreneurship

Malin Lindberg and Anders W. Johansson

Introduction

As economic growth has become an increasingly common objective on policy agendas in the Western world, new ways to promote entrepreneurship have emerged, emphasising the potential of increasing the number of entrepreneurs among groups that are now under-represented or disadvantaged. In northern Europe and North America, which are the geographical areas focused in this study, the gendered pattern of entrepreneurship in terms of men's over-representation and women's under-representation, has been particularly highlighted and addressed by public policies for growth (Orser and Riding 2006; Pettersson 2007). One applied measure is gender-sensitive business counselling, acknowledging that the prevalent gendered understanding of entrepreneurship

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as masculine hampers women's inclination to initiate and develop businesses (Nilsson 1997). This type of counselling, in particular, its incentives and characteristics, has been examined in only a limited number of research studies. Although Robson et al. (2008) suggested that neither the use of external advice nor the impact of advice is greatly influenced by gender, little is known about what the components of gender-sensitive business counselling are, and even less about the effects of such counselling on the gendered pattern and understanding of entrepreneurship. By compiling scattered scientific reports and comparing it with an empirical case, this chapter determines the specific components and effects of gender-sensitive business counselling in a novel way and thus provides a unique contribution to further development of gender and entrepreneurship as a scientific field and social practice. This is especially valuable for understanding and promoting entrepreneurship within science and technology, where the challenge is dual to change the masculine understanding of both entrepreneurship and science and technology (cf. Schiebinger 2008; Lindberg 2012).

The main purpose of the chapter is to analyse to what extent gender-sensitive business counselling implies a change in the gendered pattern and understanding of entrepreneurship. Three research questions serve to attain the purpose: What are the specific components of existing methods of gender-sensitive business counselling as reported in research studies and as reflected in the empirical case? What are the effects of existing methods of gender-sensitive business counselling as reported in research studies and as reflected in the empirical case? To what extent do the identified components and effects serve to change the gendered pattern and understanding of entrepreneurship?

Empirically, the study includes a literature review and a case study of a practical example of gender-sensitive business counselling in Sweden. The literature review is based on eight studies of gender-sensitive business counselling carried out in four countries in northern Europe and North America: Canada, the United States, the United Kingdom and Sweden. This geographical focus is motivated by the similarly gendered pattern and understanding of business, working-life and society characterising this region. The similarity is reflected in the fact that the literature review only managed to identify scientific publications on gender-sensitive business counselling emanating from this region, further discussed in the method section. The studied case, a project titled Leia Accelerator, was pursued by and for small business entrepreneurs in Sweden during 2010–2012 and the study focuses the method for expansion of gender-equal companies that was developed and tested within the project. The components and effects reported in the literature review and the empirical case are compared and analysed to address the research questions posed in this chapter.

First, this chapter describes and discusses the study methodology (Sect. 2), and then reviews existing research studies on gendered entrepreneurship and gender-sensitive business counselling (Sect. 3). The Leia Accelerator project is thereafter examined, concerning the components and perceived effects of their method for gender-sensitive business counselling (Sect. 4). The subsequent section compares the evidence from the literature review and the empirical case concerning their components and effects (Sect. 5). The comparison is thereafter analysed by means of the three research questions to elucidate the prospects of changing the masculine pattern and understanding of entrepreneurship through gender-sensitive business counselling (Sect. 6). Finally, conclusions are drawn regarding directions for further research and recommendations for future business counselling distinguishable in the analysis of the data (Sect. 7).

Methods

In this section, the methods used in the study are outlined. The study combines a compilation and examination of earlier research studies with an analysis of an empirical case in order to attain a multifaceted view on the prospects of gender-sensitive business counselling to imply a change in the gendered pattern and understanding of entrepreneurship.

The literature review was carried out using several search engines to identify publications about gender-sensitive business counselling, using the terms counselling, assistance or consulting in combination with gender, women or equality. This approach led to very few hits. Therefore, an alternative snowball technique was used for identification of existing studies, whereby reference lists of the most well-known research studies on gender-sensitive business counselling were searched to identify additional studies on this topic.[1] Thus, eight studies were found including Braidford and Stone (2008), Johansson (2008), Nilsson (1997), Orser and Findlay-Thompson (2011), Orser and Riding (2006), Robson et al. (2008), Stanger (2004) and Tillmar (2006). All of the studies emanated from northern Europe and North America, possibly due to the fact that most countries in this region have a relatively long tradition of highlighting and promoting gendered aspects of organisations and society, which might have inspired similar approaches in business counselling. Empirically, there ought to be an extensive number of examples to be identified and studied in the southern and eastern parts of the world as well, considering the widespread efforts to promote women's entrepreneurship as a means for poverty reduction and empowerment, but this is still either scientifically understudied or studied by means of other terms than the ones applied in the publication search in this study. Most of the identified studies focus on the components of existing methods of gender-sensitive business counselling, and only a few consider the effects of such counselling, possibly due to the short history of this type of counselling, limiting the access to sufficiently long-term data.

The empirical case focuses the project Leia Accelerator in northern Sweden, studied by one of the authors in 2010–2012. A Swedish case is especially appropriate for the purpose of this study due to Sweden's well-established practices of highlighting and addressing gendered patterns and understandings in various social practices and contexts, reflected in its position as the primary European contributor to published research on gender-sensitive business counselling, alongside the United Kingdom. The studied project was carried out at a business hotel managed by women entrepreneurs. The project management initiated the study in dialogue with researchers to reflect on their process of realising the aim of the project: to expand what was labelled as 'gender-equal companies'. The study was carried out by a set of methods including participatory observation, dialogue seminars, interviews and questionnaires. Participatory observation implied that the researcher participated in and documented some of the activities and meetings organised by the project. The researcher also arranged dialogue seminars to allow discussion among project participants on various gender-related topics in the project. Unless indicated otherwise, quotes presented here emanated from the dialogue seminars. Interviews meant that the researcher discussed various aspects of the project with single project participants. Entrepreneurs at Leia Accelerator completed a questionnaire every 6 months to document the development of their companies over time. The combination of these methods made it possible to pinpoint and evaluate the components and effects of Leia Accelerator's method.

The literature review and the results of the evaluation were used to assess the components and effects of existing methods of gender-sensitive business counselling. However, it is difficult to prove actual effects of these methods because the link between cause and effect is not easy to pinpoint. It is especially tricky to evaluate complex social practices such as business counselling, where it is almost impossible to separate specific factors from other possible ones. Even if positive effects can be detected, it is not certain which particular features of the counselling services caused those effects (Hjalmarsson and Johansson 2003; Orser and Riding 2006). To assess the effects of counselling services, a number of approaches have been suggested. Some advocate an evaluation in which the performance of the recipients of advisory services is compared with other groups of individuals or enterprises, such as those that do not receive such support (Norrman and Bager-Sjögren 2010). Only one of the identified studies of gender-sensitive business counselling (Orser and Riding 2006) employed such a comparative approach. The empirical study presented here did not allow comparison because of practical and financial circumstances. Even when a comparative design is employed, the problem of excluding other possible factors remains.

Triangulation is another way of pinpointing the causal relation between means and effects. Orser and Riding (2006) suggested that evaluation of business counselling should include at least three types of data: (1) performance improvements, (2) client assessments of the value of the counselling services and (3) input from multiple sources (managers, trainees, graduates, and advisory committee members). The accuracy of the evaluation is improved when several types of data are used, which can be assessed for the degree of congruence—or incongruence—among different sources. Therefore, this triangulation could indicate a causal relationship between means and effects by comparing the perception of different sources. The literature review and case study presented in this chapter were designed in this manner, comparing evidence from various sources and, thus, distinguishing probable relationships between means and effects in gender-sensitive business counselling. However, this kind of effect evaluation does not specifically pinpoint the effects of counselling services on the gendered pattern and understanding of entrepreneurship, which is why we used Hjalmarsson and Johansson's (2003) two theoretical concepts: client identity and 'clientifying' power, which are further explained in the analysis section.

Literature Review

This section reviews existing research studies on gender-sensitive business counselling, with regard to the components and effects of specific methods. In order to contextualise the literature review, it is preceded by an account of research studies on the gendered pattern and understanding of entrepreneurship.

Gendered Entrepreneurship

This section presents an account of research studies on the gendered pattern and understanding of entrepreneurship, distinguishable as symbols, practices, identity and networks. This provides a background for assessing the prospects of components and effects of gender-sensitive business counselling to change the masculinised entrepreneurship in northern Europe and North America.

Symbols and Practices of Gendered Entrepreneurship

Extensive research has concluded that entrepreneurship is primarily associated with men and certain forms of masculinity (cf. Ahl 2002; de Bruin et al. 2006; Lewis 2006; Lindgren and Packendorff 2009; Pettersson 2012). This association is made on a symbolic level and is noticeable in the social interaction among people in organisations and society (cf. Acker 1999; Gunnarsson et al. 2003). Due to this masculine understanding of entrepreneurship, women generally are to less extent than men expected to be entrepreneurial and able to run a business (De Bruin et al. 2006). The symbolic association contrasts to the fact that both men and women run businesses in practice, although to a varying extent in a masculine pattern of entrepreneurship. Hanson (2009, p. 249) described how a gendered understanding affects the perception and reception of different entrepreneurs:

> Many people and institutions continue to treat all women (or men) according to preconceived beliefs about femininity and masculinity, assuming that certain abilities and behaviours are the norm for each gender.

Studies in northern Europe and North America have shown that women generally have some difficulty identifying themselves as entrepreneurs partly because entrepreneurship is associated with men and certain kinds of masculinity and partly because many women entrepreneurs have previously primarily worked in the public sector that has been characterised by employment rather than entrepreneurship (cf. Ahl 2002; de Bruin et al. 2006; Hanson 2009; Pettersson 2012). Because of the gender-segregated labour market characterising the northern parts of the Western world, women primarily run companies within the services and creative industries (cf. Hanson 2009; Lindberg 2012). Women, therefore, have to overcome a number of structural barriers as entrepreneurs related to the gendered pattern and understanding of entrepreneurship. Tillmar (2006, p. 95) pinpointed these barriers by nuancing the notion of women and men as homogeneous groups:

> Women as business owners are just as heterogeneous a group as male business owners, but have in common the fact that they also encounter disadvantages originating from the gender-system in society.

Accounts of barriers for women entrepreneurs confirm Hanson's (2009) conclusion that location influences entrepreneurship. The entrepreneur's personal networks, which are often the strongest in their immediate environment, determine the entrepreneur's access to crucial resources for business development. These obstacles for women's entrepreneurship— manifested in the statistical under-representation of women as entrepreneurs—have determined public efforts to increase the number of women entrepreneurs in northern Europe and North America as a part of political agendas for growth, poverty reduction, gender equality and empowerment.

Identity and Networks Changing Gendered Entrepreneurship

The theoretical stream of 'doing gender' claims that it is possible—although not easy—to change gendered patterns, because every structure is created by repeated acts in which people 'do' gender in social interactions (Acker 1999; Fenstermaker and West 2002; West and Zimmerman 1987). Hanson (2009, p. 254) argued that entrepreneurship is an area with extraordinary potential to change gender stereotypes:

> Entrepreneurship is a process that is marked by deep stereotypical gender divisions, but it is also one through which people are changing the meaning of gender and the ways in which gender is lived.

This potential derives from the fact that ownership of companies gives women greater influence over the society's resources as well as increased legal and organisational power. Entrepreneurship also entails greater visibility for women and greater opportunity to serve as role models. Established women entrepreneurs play an important role as mentors for women with newly established firms (Hanson 2009; Hanson and Blake 2009). Hanson and Blake (2009, p. 143) emphasised the importance of role models for women's entrepreneurship:

> […] women will be more likely to become entrepreneurs in places where there are already a large number of women business owners who can serve as role models and mentors.

A global study of women's entrepreneurship revealed that increased confidence and access to networks are two major incentives for women's entrepreneurship. Confidence includes optimism, self-confidence and reduced fear of failure. Networks with other entrepreneurs are claimed to be even stronger predictors of women's entrepreneurship than educational level (Allen et al. 2007). Not only do networks enhance the start of new ventures among women, but they also determine the success of these ventures (Hanson and Blake 2009).

Gender-Sensitive Business Counselling

This section discusses several scientific studies that outline the emergence of methods for gender-sensitive business counselling as well as the components and effects of such counselling. The literature review was based on eight studies of gender-sensitive business counselling carried out in four countries in northern Europe and North America: Canada, the United States, the United Kingdom and Sweden (specifically, Braidford and Stone 2008; Johansson 2008; Nilsson 1997; Orser and Findlay-Thompson 2011; Orser and Riding 2006; Robson et al. 2008; Stanger 2004; Tillmar 2006). According to these studies, business counselling specifically targeting women has been conducted with public funds since the 1990s in northern Europe and North America. Such services are usually designed differently from general business counselling services, acknowledging that gendered understanding of entrepreneurship affect women's inclination to run businesses. In this sense, they can be considered to represent 'gender-sensitive' business counselling.

Emergence of Methods for Gender-Sensitive Business Counselling

Historically, business counselling has predominately targeted men in men-dominated industries such as agriculture and manufacturing industries (Hjalmarsson and Johansson 2003; Johansson 1997, 2008; Nilsson 1997). This raised problems when actors from other industries, for example, women in services and creative industries, began to seek advice for initiating or expanding businesses in the 1990s. The advisors were unable to meet the new demand, partly due to lack of proper knowledge of industries other than the ones they had usually handled and partly due to the prevalent masculine understanding of entrepreneurship, underestimating women's entrepreneurial potential (Hanson 2009; Johansson 2008; Lindberg et al. 2012; Tillmar 2006). Some women entrepreneurs experienced 'not being taken seriously' and a 'lack of respect' from business counsellors (Orser and Findlay-Thompson 2011, p. 398; Orser and Riding 2006, p. 146). Previous research concludes that few regular support systems in northern Europe have managed to acknowledge and address the gendered pattern and understanding of entrepreneurship (Johansson 2008; Pettersson 2012). This inability to meet women's demands led to the development of alternative counselling methods, such as peer-to-peer coaching in networks of women entrepreneurs and Women's Resource Centres, initiated in Sweden in the early 1990s and spread throughout Europe in the 2000s, offering counselling, meeting places and networks for women (Lindberg et al. 2012).

Business counselling services directed exclusively towards women have generally been motivated by the fact that women face different barriers in their business life from men because of gendered patterns and understandings in organisations and society (Nilsson 1997; Tillmar 2006). Banks, advisors, officials, journalists and customers perceive and receive men and women differently as entrepreneurs due to the prevalent masculine pattern and understanding of entrepreneurship. Gender-sensitive business counselling takes into account that women's experiences of working-life and business-life often differ from men's, partly because of the generally higher estimation of men's working efforts distinguishable in higher salaries, positions, status etc. and partly because of the gender-segregated labour market in northern Europe and North America where women mainly work in the service sector and men in basic and manufacturing industries. Tools for challenging and changing the gendered pattern and understanding of entrepreneurship are provided in gender-sensitive business counselling by balancing women's joint experiences of being marginalised within entrepreneurship by a simultaneous acknowledgement of the multiplicity of experiences, circumstances and career aspirations among women (Nilsson 1997).

The components of these alternative services differ somewhat from traditional types of business counselling, which are often based on a hierarchical relationship between advisors and entrepreneurs. Traditional business counselling considers the advisor to be an 'expert' able to assess the viability of other persons' business ideas (cf. Braidford and Stone 2008; Hjalmarsson and Johansson 2003; Johansson 1997, 2004, 2008; Nilsson 1997; Tillmar 2006). In a comparative study of traditional and alternative business counselling, Johansson (2008, p. 56) characterised the traditional relationship between counsellor and client as 'highly asymmetrical' based on a distinct superiority/inferiority. This asymmetrical relationship depicts the counsellor as 'a professional helper' and the client as 'needy' (Hjalmarsson and Johansson 2003, p. 89). Alternative forms of counselling entail a more symmetrical relationship, in which the superiority/inferiority between the counsellor and the client is blurred (Johansson 2008). The counsellor then acts as a sounding board and provider of creative arenas where entrepreneurs learn from each other, rather than a provider of expert advice. In advisory processes, the power relation between the advisor and the client is highly relevant for pinpointing the essence of alternative types of business counselling (Hjalmarsson and Johansson 2003).

Reported Components and Effects of Gender-Sensitive Business Counselling

From the literature review, eight categories of reported components of gender-sensitive business counselling were identified: client segmentation, counsellor profiling, symmetrical counselling, managerial counselling, social counselling, tailored counselling, courses and seminars and networks and role models. The specific components within each category are listed in Table 6.1.

Despite the very limited literature, three categories of reported effects of gender-sensitive business counselling could be identified: economic

Table 6.1 Reported components of gender-sensitive business counselling

Client segmentation Gender-aware client recruitment to avoid masculine norms of entrepreneurship (Tillmar 2006) Inclusion of growth-reluctant or part-time entrepreneurs (Nilsson 1997) More multifaceted client-segmentation than just "women" (Braidford and Stone 2008; Nilsson 1997; Orser and Findlay-Thompson 2011)	**Counsellor profiling** Women counsellors for women entrepreneurs (Nilsson 1997; Orser and Riding 2006) Women entrepreneurs' managing programs to support other women entrepreneurs (Orser and Riding 2006) Business counsellors trained in gender issues (Tillmar 2006)
Symmetrical counselling Symmetrical relation between counsellor and client (Johansson 2008) Coaching by a future- and development-oriented dialogue (Pettersson 2012; Tillmar 2006)	**Social counselling** Inclusion of both economic and social aspects of entrepreneurship (Nilsson 1997) Acknowledging work-life balance (Orser and Findlay-Thompson 2011)
Managerial counselling Business-planning assistance, such as market research (Orser and Riding 2006) Economic advice on marketing, budgeting, funding, taxation (Nilsson 1997; Pettersson 2012) Managerial, educational, psychosocial support (Orser and Findlay-Thompson 2011)	**Tailored counselling** Measures tailored to the specific circumstances and the specific entrepreneur (Tillmar 2006) Measures tailored to the characteristics of service-sector firms (Orser and Findlay-Thompson 2011; Robson et al. 2008)
Courses and seminars Courses and seminars to increase women's entrepreneurial skills (Nilsson 1997; Orser and Riding 2006) Courses and seminars to empower women mentally (Nilsson 1997; Pettersson 2012) Seminars on sales, rhetoric, stress, leadership, customer orientation, and board work (Tillmar 2006) Seminars and exchange of experiences about the gender system (Tillmar 2006)	**Networks and role models** Networking for exchanging personal and professional experiences among women entrepreneurs (Johansson 2008; Nilsson 1997; Orser and Findlay-Thompson 2011; Orser and Riding 2006; Pettersson 2012) Meeting places for women entrepreneurs (Johansson 2008; Nilsson 1997) Mentorship and role models (Orser and Findlay-Thompson 2011; Orser and Riding 2006; Pettersson 2012)

Table 6.2 Reported effects of gender-sensitive business counselling

Economic effects	Managerial effects	Psychological effects
Expansion of business (Orser and Riding 2006)	Changed perception of their businesses (Tillmar 2006)	Mental development (Nilsson 1997)
Increased export (Orser and Riding 2006)	Changed perception of themselves as business managers (Tillmar 2006)	Feelings of empowerment, comfort, and support (Orser and Findlay-Thompson 2011)
Better understanding of financial risks (Orser and Riding 2006)	A more structured, goal-oriented and professional approach (Tillmar 2006)	Confirmation through sharing experiences with other women entrepreneurs (Tillmar 2006)
More adequate price-setting of products/services (Orser and Riding 2006)	Strengthened and clarified leadership role (Tillmar 2006)	Strengthening the entrepreneurial identity by networking with other women entrepreneurs (Johansson 2008)
New customer contacts by networking with other women entrepreneurs (Johansson 2008)	Management skills development as growth strategy (Orser and Findlay-Thompson 2011; Orser and Riding 2006)	
	Advice on entrepreneurial matters by networking with other women entrepreneurs (Johansson 2008)	
	A greater openness to cooperation (Tillmar 2006)	

effects, managerial effects and psychological effects. The specific effects of each category are listed in Table 6.2.

Leia Accelerator's Method to Expand Gender-Equal Companies

This section outlines the components and effects of Leia Accelerator's method of gender-sensitive business counselling.

The Leia Accelerator project aimed to expand gender-equal companies by forming and testing a specific method for gender-sensitive business counselling. 'Gender-equal companies' were defined as a matter of ownership, designating firms owned by at least 50% by a woman. Expansion was measured by the following six aspects: turnover, working time, employees, trainees, cooperation and external services. The European Union's Regional Development Fund, the Västerbotten region, and the Umeå municipality financed the project. The project was carried out at a business hotel, established by a group of women entrepreneurs, covering 2 floors and 24 entrepreneurs—including part-time entrepreneurs—in various services industries (for example, personal and professional coaching, corporal treatments, stress management, journalism, interior decoration, printing services and publishing). Almost all of the tenants were women, although the number of men increased slightly after changed recruiting procedures. The gender-segregated labour market was reflected in the industries represented at the business hotel in that women often run companies within the services and creative industries (cf. Hanson 2009; Lindberg 2012). Daily interaction among entrepreneurs was intended to generate new knowledge, new partners, new business ideas and new clients. This process was supported through seminars and coaching, described in detail below. One of the tenants described the difference between Leia Accelerator and regular counselling services:

> I felt that it was a difference in focus. [The business advisor] I was going to, focused more on risks and on doing an analysis of potential

> competitors and of what's [profitable] […] Here [at Leia] there is more focus on what is possible and inspiring. My mentor […] knows a lot about business plans and economy and such things […] [Leia] does not dramatise so much, which means that one sees what is possible and that it is not something abnormal [about running your own business as a woman]. It has done much for me.

The main incentive for developing and testing Leia Accelerator's method for gender-sensitive business counselling was their perceived need for alternatives to those provided by other business-supportive environments, where the gendered pattern and understanding of entrepreneurship were not acknowledged or addressed. The method designed by Leia Accelerator underlines that business counselling does not need to focus on risks, competition, or elitism, as assumed in most other counselling methods. Instead, it can just as well focus on opportunities, cooperation and inclusion. When entrepreneurs dare to be open with their thoughts, experiences and strategies, they can inspire each other in a way that further develops their businesses. This represents an alternative standard of business counselling in which teamwork enhances success and entrepreneurs support each other's development through generous sharing of experiences. Leia Accelerator's method was based on horizontal relationships in which entrepreneurs help each other to realise their business ideas via peer learning and networking. It is thus intended both to expand the entrepreneurs' networks and to make them more confident and self-evident in their identity as entrepreneurs.

One participant described the gendered aspects of Leia's version of business counselling this way:

> Men [entrepreneurs] are perhaps intrigued by problems and difficulties […] while women [entrepreneurs] need other incentives to grow. Often, [women entrepreneurs] are already too aware of their flaws and mistakes. They need more to lift, [which] is a big difference. That is what feels good at Leia, I think, that you lift. There you can be open with your mistakes and assure each other that it is okay, it is just to move on. I think that is the main difference: that we [as women] really need to be lifted.

Components of Leia Accelerator's Method

Leia Accelerator's method to expand gender equal businesses consisted of five main components:

1. Meeting place
2. Coaching
3. Seminars
4. Expanded networks
5. Conceptualisation

The *meeting place* included offices at a joint venture hotel run by Leia Accelerator, which the entrepreneurs rented. There were also conference rooms, meeting rooms and lunchrooms. The entrepreneurs could easily participate in spontaneous meetings in hallways and lunchrooms and planned meetings in offices and meeting rooms. The common areas also provided a professional setting for the businesses, given that many of the entrepreneurs previously worked from their private homes. The uniform design of the premises, in line with Leia Accelerator's graphic brand, further reinforced the professional framing.

Three different types of *coaching* were available at Leia Accelerator: individual coaching, coaching in small groups and coaching in large groups. Coaching supports the entrepreneurs' efforts to develop their businesses through establishing and realising professional goals. The coach acts as a sounding board rather than an expert advisor. The combination of individual and group coaching at Leia was intended to speed up the companies' development, since there were certain themes that the entrepreneurs preferred to discuss in private with a coach, and others that were rewarding to deal with by getting inspiration from each other. Of particular importance was the exchange of experiences between new and established entrepreneurs.

The *seminars* arranged at Leia Accelerator include thematic workshops and seminars with established women entrepreneurs as role models. Thematic seminars followed a topic chosen for each occasion according to participants' current needs. Examples included sales, economy and personal effectiveness. Role-model seminars were organised to inspire the entrepreneurs through external lecturers who had achieved something special in their ventures.

Through *expanded networks,* entrepreneurs at Leia widened their potential customer base and increased their access to skills other than their own. They were encouraged to share their own networks with each other, with the intention of creating a 'win-win-win situation' that not only benefited a single company, but also other companies as well as the customers.

Through *conceptualisation,* entrepreneurs at Leia developed joint concepts such as joint activities, brands, projects or new businesses. Conceptualisation was based on the assumption that structured interaction among businesses increases the customer base, sales/turnover and innovation. For example, a group of entrepreneurs at Leia developed the joint brand 'Sustainable Health' which included joint marketing activities and common services for the sale of services related to personal well-being.

Effects of Leia Accelerator's Method

A recurring survey completed by the entrepreneurs at Leia Accelerator showed that 80% of them had expanded in at least two of the six measurements (turnover, working time, employees, trainees, cooperation and external services). The most common form of expansion was increased cooperation followed by increased purchase of external services. The least frequent form of acceleration was increased number of employees, followed by increased number of trainees. Although the various aspects of expansion can be measured separately, they probably affect each other. Each aspect can be considered to represent a different stage of business development. That most companies at Leia expanded in terms of increased cooperation and external services may reflect that these activities are the first steps of business development. Hiring trainees or employees might then be a later step, and increased sales the last step of development. Alternatively, increased turnover can be seen as a prerequisite to hiring staff.

The project management embraced the idea that more advanced companies would inspire those less advanced, accelerating the transition between different phases. Some companies acted as forerunners for the others by using the techniques that the method advocates, especially expanded networks, coaching and conceptualisation. Thus, they have succeeded in developing their businesses at a relatively fast pace. They also have started up several new businesses during their stay at Leia, in collaboration with each other and external entrepreneurs.

Several of the entrepreneurs stated that access to an office was an important part of their expansion since many of them previously managed their businesses from their private homes. Moving to Leia Accelerator strengthened their identity as entrepreneurs and increased their confidence in their businesses. Having an office also enabled the entrepreneurs to receive customers in a more professional manner. Access to meeting and conference rooms was also described as useful for their business life. Participants—especially those companies arranging lectures and courses—frequently used the two conference rooms. When asked why she chose to move to Leia and not another business hotel, one business owner stated:

> I fancy the combination of training and development. There are also [several other companies] active in the same industry as mine, but also in other industries, so that I feel at home and stimulated by others.

Several entrepreneurs emphasised the importance of the social environment at Leia. One of the Leia's most commonly mentioned benefits was having colleagues and pleasant company in daily life. The social environment at Leia was portrayed as inspiring and open, a place where entrepreneurs support and help each other. One entrepreneur stated:

> It is a good working environment where people talk with each other and where you get new ideas. We acknowledge each other and that contributes with a lot compared with sitting at home itself. The daily discussions, or the possibility of it, are important.

Thus, the Leia environment was described as having not only social significance but also professional benefits. The entrepreneurs developed their business ideas in interaction with each other. The exchange with other companies contributed to more business contacts and increased participation in various networks. Not least important, entrepreneurs made contact with people with other skills than their own. One entrepreneur described how she made new contacts when participating in an event at Leia:

> There [were] a lot of interesting people [whom] I think I will have contact with in the future […] It is, of course, great fun when something happens and when I meet new persons with whom I perhaps can move forward.

The everyday life at Leia gave rise to new assignments, as one of the entrepreneurs testified:

> [I] received orders that I might not have received [otherwise]. Just because the other entrepreneurs are reminded of your existence daily, you are mentioned in various contexts.

The mutual benefit of the entrepreneurs at Leia Accelerator emerged not only from the everyday life together but also from a conscious strategy to encourage collaboration, which permeates Leia's method. The most formalised collaboration that occurred at Leia was a constellation of coaching businesses jointly establishing a new company. The joint brand 'Sustainable Health' was another example of extensive collaboration among the entrepreneurs. There were also several examples of smaller collaborations concerning specific activities. Two of the companies developed a joint lecture, combining their competences within culture and health. Another entrepreneur organised an open house on the theme 'house, room, kitchen' where entrepreneurs with different skills and products/services interacted.

Comparing Components and Effects of Gender-Sensitive Business Counselling

This part of the chapter compares the evidence from the literature review and the case study concerning the specific components and effects of gender-sensitive business counselling in order to, in the subsequent section, analyse to what extent they serve to change the gendered pattern and understanding of entrepreneurship.

Table 6.3 Comparison of components in gender-sensitive business counselling

Components	Literature review	Case study
Client segmentation	• Gender-aware client recruitment • Inclusion of growth-reluctant or part-time entrepreneurs • More multifaceted client-segmentation than just "women"	• Recruitment of gender equal businesses • SMEs, including part-time entrepreneurs
Counsellor profiling	• Women entrepreneurs' managing programs supporting other women entrepreneurs • Women counsellors for women entrepreneurs • Business counsellors trained in gender issues	• Women entrepreneurs' managing programs supporting other women entrepreneurs
Symmetrical counselling	• Symmetrical relation between counsellor and client • Coaching by a future and development oriented dialogue	• Individual and group coaching
Managerial counselling	• Business planning assistance, such as market research • Economic advice on marketing, budgeting, funding, taxation • Managerial, educational, psychosocial support	• Individual and group coaching • Thematic seminars (sales, effectiveness, economy)
Social counselling	• Inclusion of both economic and social aspects of entrepreneurship • Acknowledging work-life balance	• Business hotel • Role models
Tailored counselling	• Measures tailored to the specific circumstances and the specific entrepreneur • Measures tailored to the characteristics of service-sector firms	• Individual and group coaching

(continued)

Table 6.3 (continued)

Components	Literature review	Case study
Courses and seminars	• Courses and seminars to increase women's entrepreneurial skills • Courses and seminars to empower women mentally • Seminars on sales, rhetoric, stress, leadership, customer orientation, board work • Seminars and exchange of experiences about the gender system	• Role-model seminars • Thematic seminars
Networks and role models	• Networking among women entrepreneurs • Meeting places for women entrepreneurs • Mentorship and role models	• Business hotel • Increasing skills and customer base • Role-model seminars

Comparing Components

This section compares the components of gender-sensitive business counselling as presented in Table 6.3.

The table illustrates both the similarities and the differences emerging from the comparison of the components identified in the literature with the empirical case:

- Regarding ***client segmentation***, both the literature review and the case study advocate gender-aware client recruitment in the sense of prioritising companies that are run by women—either alone or together with a partner (man or woman). Both welcome small businesses and part-time entrepreneurs. This strategic recruitment of women and SMEs reflects the basic intention of gender-sensitive business counselling to challenge the association among entrepreneurship, men and certain forms of masculinity, and therefore can be interpreted as a response to Hanson's (2009) observation that gendered stereotypes affect the perception and reception of women entrepreneurs. However, the literature review underlines the importance of more sophisticated client segmentation than just women, which is not evident in Leia Accelerator. The transition from women-only businesses to gender-equal businesses in Leia's recruitment strategy might be interpreted as an increased level of client segmentation. More sophisticated client segmentation has its scientific counterpart in the theoretical stream of 'doing gender' highlighting the processes wherein gendered categorisations are continually constructed either in a dualistic or a multifaceted manner (cf. Acker 1999; Fenstermaker and West 2002; West and Zimmerman 1987).

- Concerning ***counsellor profiling***, both the literature review and the case study entail women entrepreneurs managing programs that support other women entrepreneurs, which reflects the importance of established women entrepreneurs acting as role models and mentors for nascent women entrepreneurs (cf. Hanson 2009; Hanson and Blake 2009). The literature review discerns having women counsellors for women entrepreneurs and business counsellors trained in gender issues as important components, which is not as evident in Leia's method. This might be interpreted as an example of the crucial role of location for women's businesses, in that their business development depends on approximate resources provided by counsellors, financiers, public agencies and so on (cf. Hanson 2009).
- ***Symmetrical counselling*** is a core feature discerned both in the literature review and the case study, characterised by equal relations between counsellors and clients as well as coaching through future- and development-oriented dialogues. This approach challenges the hierarchical relationship between the counsellor as 'expert' and the client as 'novice' identified in traditional business counselling (cf. Braidford and Stone 2008; Hjalmarsson and Johansson 2003; Johansson 1997, 2004, 2008; Nilsson 1997; Tillmar 2006).
- ***Managerial counselling*** is present in both cases in terms of thematic guidance in economy, management and sales. While most of the other components clearly signal gender-sensitivity, managerial counselling is very similar to mainstream business counselling marked by masculine norms. However, the features of managerial counselling identified at Leia Accelerator differ from those cited in the literature review because they used coaching and seminars rather than expert advice.

- ***Social counselling*** is also discernible in both cases, acknowledging both the economic and social aspects of entrepreneurship. However, Leia's method did not explicitly address work-life balance, except through thematic seminars on personal effectiveness. This combination of managerial and social counselling is an example of how place—in terms of immediate social relations—is recognised as an important feature of women's entrepreneurship (cf. Hanson 2009).
- ***Tailored counselling*** is featured in both cases, implying measures tailored to the specific circumstances (e.g. industry) and the specific entrepreneur. This might contribute to gender-sensitivity by enabling many different 'doings' of gender rather than only the traditional ones, as emphasised in the theoretical stream of 'doing gender' (cf. Acker 1999; Fenstermaker and West 2002; West and Zimmerman 1987). Measures tailored to the characteristics of service sector firms is not evidently present in Leia's method, but might still exist since most companies at the business hotel belonged to that sector. This kind of tailoring is called for since women in the gender-segregated labour markets in northern Europe and North America primarily run companies within the services and creative industries (cf. Hanson 2009; Lindberg 2012).
- ***Courses and seminars*** are a central feature in both cases, even if Leia's method does not entail explicit exchange of experiences about gendered patterns and understandings in organisations and society.
- ***Networks and role models*** constitute one of the most prominent components according to existing studies and the empirical case. Leia's method provides a meeting place in terms of a business hotel besides more temporal sites for networking. This corresponds to existing studies, identifying access to networks and role models as two main boosters of women's entrepreneurship (cf. Allen et al. 2007; Hanson 2009; Hanson and Blake 2009).

Comparing Effects

This section compares the evidence from the literature review and the case study concerning the effects of gender-sensitive business counselling as presented in Table 6.4.

Table 6.4 Comparison of effects in gender-sensitive business counselling

Effects	Literature review	Case study
Economic effects	• Expansion of business • Increased export • Better understanding of financial risks • More adequate price-setting of products/services • New customer contacts by networking with other women entrepreneurs	• Expanded networks • Increased business contacts • Increased collaboration • Increased external services
Managerial effects	• Changed perception of their businesses • Changed perception of themselves as business managers • A more structured, goal-oriented, and professional approach • Strengthened and clarified leadership role • Management skills development as growth strategy • Advice on entrepreneurial matters by networking with other women entrepreneurs • A greater openness to cooperation	• Strengthened entrepreneurial identity • Increased business confidence • Joint brands and businesses
Psychological effects	• Mental development • Feelings of empowerment, comfort and support • Confirmation through sharing experiences with other women entrepreneurs • Strengthening the entrepreneurial identity by networking with other women entrepreneurs	• Strengthened entrepreneurial identity • Increased business confidence

The table illustrates both the similarities and differences between perceived effects in the literature review and the case study.

- ***Regarding economic effects***, Leia may not have been in operation long enough to enable a proper assessment. Despite this, both cases identify various signs of business expansion, of shifting character in each case. The literature review identifies mostly traditional economic effects, such as expansion, export, price-setting etc., with exception from new customer contacts by networking with other women entrepreneurs. The empirical case displays less traditional effects, such as expanded networks and increased business contacts, collaboration and external services.

- ***Concerning managerial effects***, the literature review indicates a wider range of effects than those perceived in the empirical case. The companies at Leia claimed to have strengthened their entrepreneurial identity and increased their business confidence, which is similar to the accounts in the literature review of changed perception of their businesses and of themselves as business managers. Advice on entrepreneurial matters through networking with other women entrepreneurs is reported in the literature review studies and also seems to have occurred at Leia Accelerator, both informally in the corridors and formally in group-coaching sessions.
- ***The psychological effects*** seem to be similar in the literature review and the case study, including confirmation, comfort and support as well as strengthened business confidence. These effects can be understood in the light of existing literature, indicating that women often have some difficulty identifying themselves as entrepreneurs because of the masculine pattern and understanding of entrepreneurship and the widespread experience among women in northern Europe and North America of previous work in the public sector (cf. Ahl 2002; de Bruin et al. 2006; Hanson 2009; Pettersson 2012).

Discussion

This section analyses the comparison in the preceding section with regard to each of the three research questions guiding the study to elucidate the prospects of changing gendered structures of entrepreneurship through gender-sensitive business counselling.

(i) The first research question was: What are the specific components of the existing methods of gender-sensitive business counselling as reported in research studies and as reflected in the empirical case?

The literature review identified eight categories of components: client segmentation, counsellor profiling, symmetrical counselling, managerial counselling, social counselling, tailored counselling, courses and seminars and networks and role models. The same components were also identified in the Leia Accelerator case, albeit with some differences. While some of the identified components seem to be specific to gender-sensitive business counselling (for example, symmetrical counselling, social counselling and networks/role models), others are very similar to general counselling methods (client segmentation, managerial counselling, tailored counselling and courses/seminars). It can, however, be distinguished that the *way* in which the latter components are carried out determines their gendered effects, rather than their mere prevalence. For example, the component client segmentation occurs in general counselling methods, segmenting firms according to size, age or niche. In gender-sensitive counselling, firms are segmented according to specifically gendered aspects such as the owner's gender, the part-time work specific to women's entrepreneurship or the specification of different target groups among women. The component of courses/seminars occurs in general counselling as well, but in gender-sensitive counselling, this component specifically implies peer learning among women entrepreneurs and the use of experienced women entrepreneurs as role models. In addition, managerial counselling occurs in general counselling, but it is there often permeated by a masculine understanding of entrepreneurship, which in gender-sensitive business counselling is challenged by an active client role and a supportive consultant role based upon equal power relations, as illustrated by Leia Accelerator's co-coaching strategy (cf. Hjalmarsson and Johansson 2003; Johansson 1997, 2008; Nilsson 1997). Lessons to be learnt by comparing the literature review with the case study primarily regard the value of triangulation when attempting to distinguish specific components of existing methods of gender-sensitive business counselling. While the literature review provides an encompassing overview of recurrent components that is valuable as a general insight, the empirical case contributes to a more detailed account of components that is valuable as a specific insight. By comparing the general and specific insights, the contextual validity of the study is increased in terms of ability to reflect the multifaceted character of complex social practices such as gender-sensitive business counselling. Such validity enhances the subsequent analysis of to what extent the identified components imply a change in the gendered pattern and understanding of entrepreneurship.

(ii) The second research question was: What are the effects of the existing methods of gender-sensitive business counselling as reported in research studies and as reflected in the empirical case? This study identified three categories of effects: economic, managerial and psychological effects. Both the literature review and the case study distinguish a positive effect of gender-sensitive business counselling in these three areas. This positive pattern reflects the ambition in gender-sensitive counselling methods to reach beyond a masculine understanding of entrepreneurship, where expansion in terms of increased sales and employees is favoured (cf. de Bruin et al. 2006; Hanson 2009). This is partly achieved by balancing the traditional focus on economic effects with managerial and psychological effects, highlighting the need for a more multifaceted view on business 'development' in order to better acknowledge the contribution of women entrepreneurs to organisational and societal development. The pinpointed managerial effects correspond to earlier studies that identified increased confidence and access to networks as the two main incitements for women's entrepreneurship. Also, the distinguished psychological effects of strengthening women's entrepreneurial identity are identified as crucial in earlier studies of gendered entrepreneurship (cf. Allen et al. 2007; Hanson and Blake 2009). The ambition to reach beyond a masculine understanding of entrepreneurship is thereto partly detectable as an expansion of the specific aspects traditionally considered part of economic effects, as in Leia Accelerator's acknowledgement of expanded networks and increased business contacts, collaboration and external services, alongside an increase in turnover and personnel. As in the case of components, the *way* in which effects are distinguished seems to be a crucial part of gender-sensitive business counselling, in addition to their mere prevalence. Lessons to be learnt by comparing the literature review with the case study regard primarily the value of triangulation when attempting to distinguish documented effects of existing methods for gender-sensitive business counselling. The practically detailed account from the empirical case serves to enrich the encompassing overview provided by the literature review, increasing the contextual validity through a micro/macro comparison of complex social practices.

(iii) The third research question was: To what extent do the identified components and effects serve to change the gendered pattern and understanding of entrepreneurship? The comparison between the literature review and the case study exposes a general congruence regarding the eight identified categories of components and the three categories of effects, although with some variances in emphasis and operationalisation. The general similarity does not automatically entail changes in the gendered pattern and understanding of entrepreneurship, however. By strengthening women's entrepreneurial identity, confidence and access to networks, resulting in increased economic, managerial and psychological effects, the identified components contribute to improve women's business development and thus serve to change the general masculine *pattern* of entrepreneurship in terms of a more even distribution of women and men as entrepreneurs. Nevertheless, the prevalent masculine *understanding* of entrepreneurship might remain intact, if the masculine pattern and understanding of traditional business counselling are reproduced in the gender-sensitive methods, for e.g. if the client continually is assigned a passive role and the relationship between the counsellor and the client remains asymmetrical. The matter of *how* the specific components and effects are designed and distinguished is thereby of utmost importance when studying and performing gender-sensitive business counselling. This is reflected in an earlier critique of gender-specific entrepreneurship programs, stating that entrepreneurs are best served by non-targeted programs since gender-based programs tend to reinforce rather than eliminate gender stereotypes and that specialised programs fail to acknowledge non-gendered explanations for differences in performance among companies. By underlining the need for gender-specific measures, gender-sensitive business counselling could reinforce the same segregating notions of gender that it

> intends to eradicate, which is a common dilemma in gender-equality efforts (cf. Nentwich 2006; Orser and Riding 2006). Nevertheless, as Orser and Riding (2006, p. 146) noted, 'Gender-based programs may improve training efficiency given gender-specific obstacles and challenges faced by some women entrepreneurs', which is similar to the arguments raised in this chapter. Therefore, the prevailing need may basically be for business counselling methods that acknowledge the structural barriers women face in organisations and societies marked by a masculine pattern and understanding of entrepreneurship, rather than for business counselling targeting women only because of their gender per se.

To further elucidate *how* the specific components and effects of gender-sensitive business counselling are designed and distinguished in a way that serves to truly change the gendered pattern and understanding of entrepreneurship, two concepts elaborated by Hjalmarsson and Johansson's (2003) will be used: client identity and 'clientifying' power. The first concept, client identity, pinpoints the role of the client vis-à-vis the consultant, emphasising that the client needs to adopt an active role in the counselling process since strategic issues such as business development require collaboration between client and counsellors (cf. Puutio et al. 2008). The counsellor profiling and the symmetrical counselling identified as gender-sensitive components in both the literature review and the case study clearly indicate the client's active role in setting and realising business development goals. The identified managerial and psychological effects also reflect the clients' active role through improved perception of their businesses and themselves as business managers. However, the managerial and social counselling might entail a passive role for the client if the counsellor is designated an expert role in communicating these matters. The same goes for courses and seminars that may be designed to focus on expert knowledge and one-way communication between teachers and students. The second concept, 'clientifying' power, refers to the power relation between the client and counsellor, emphasising that 'symmetric power relations are necessary in order to establish a dialogue and a genuine collaboration between client and consultant' (Hjalmarsson and Johansson 2003, p. 95–96). The symmetrical counselling, networking and role models identified both in the literature review and in the case study clearly reflect symmetric power relations between counsellor and client. The psychological effects in terms of empowerment, comfort and support also can be indicators of equal power distribution. Nevertheless, some components might imply an asymmetrical relationship between counsellor and client. The counsellor profile is for example—in the cases of women counsellors for women entrepreneurs and women entrepreneurs managing programs supporting other women entrepreneurs—no guarantee for equality. Neither do managerial counselling, social counselling or courses and seminars necessarily imply symmetrical relationships.

It could be argued that empowering women as entrepreneurs by promoting an active client identity and enabling clientifying power imply a change of the gendered pattern and understanding of entrepreneurship by enhancing the development of women's businesses, which means that their visibility as entrepreneurs is increased in a manner that provides role models for other women as potential entrepreneurs (cf. Hanson and Blake 2009). More women developing their companies, thereto changes the gendered pattern of entrepreneurship by levelling the number and men running businesses and the gendered understanding of entrepreneurship by increasing women's legal, financial and organisational powers (cf. Hanson 2009). In these respects, gender-sensitive business counselling does serve to change the gendered pattern and understanding of entrepreneurship. However, in cases where passive roles and asymmetrical relations prevail, despite empowering ambitions of gender-sensitive business counselling, it is, however, doubtful if this type of counselling truly alters the prevalent gendered pattern and understanding of entrepreneurship. As a passive receiver of expert advice, the client may very well be able to develop her business, although not as strategically as in a more active and equal setting (cf. Hjalmarsson and Johansson 2003). But it does not entail a fundamental change of those gendered power relations that permeate masculinised entrepreneurship.

The triangulation of data in this chapter, combining a literature review with a case study, has proven to provide a multifaceted view on the prospects of gender-sensitive business counselling to imply a change in the gendered pattern and understanding of entrepreneurship, able to reflect complex social practices of business development and business counselling. Due to the well-established practices in northern Europe of acknowledging and addressing gender in various social practices, the focused Swedish case has provided examples of advanced practices of gender-sensitive methods for business counselling, ascribing women entrepreneurs the active client identity and clientifying power required to challenge and change the masculine pattern and understanding of entrepreneurship.

Conclusions

In this final section, conclusions are drawn regarding directions for further research and recommendations for future business counselling as distinguished in the analysis of the data.

By compiling scattered scientific reports and comparing them with an empirical case, the chapter has determined specific components and effects of gender-sensitive business counselling, serving to further develop gender and entrepreneurship as a scientific field by provision of new data on macro and micro level combined with an analytical approach able to pinpoint the power-related dynamics of masculinised entrepreneurship. According to the analysis, gender-sensitive business counselling serves to change the gendered pattern and understanding of entrepreneurship, when designed to ascribe women entrepreneurs an active client identity and clientifying power. The *way* in which components are designed and effects are distinguished is thus crucial in gender-sensitive business counselling, in addition to the prevalence of certain components and effects. Eight components and three effects are identified in this study of which some are specific for gender-sensitive business counselling and some are similar to general counselling methods but with differing operationalisation. To deepen these insights, future studies could further pinpoint the relation between the *what* and *how* in gender-sensitive business counselling by additional data collection and refined analytical frameworks. Data from a wider range of organisational and geographical contexts could thereto contribute to increased understanding of the complexity of social practices in business development and business counselling. Since this study focuses northern Europe and North America, it is still unclear if global variations in the gendered pattern and understanding of entrepreneurship affect the efficacy of different components and effects of gender-sensitive approaches, which could be extricated through more all-encompassing study designs or multiple parallel regional studies, for example in Asia, Africa and South America. Future studies could also serve to identify different understandings of 'gender-sensitive' in various settings, for example, concerning entrepreneurship within science and technology that is characterised not only by a masculine pattern and understanding of entrepreneurship but also of science and technology. It could then be elucidated if different understandings in different settings evoke different effects on gendered entrepreneurship, inspired by the nascent scientific stream of critical studies of gender equalities (cf. Magnusson et al. 2008).

Recommendations for future business counselling primarily concern the *what* and *how* of gender-sensitive business counselling, prescribing a strategical combination of a selection of gender-specific components among the ones identified in this chapter and a selection of general components designed in a way that ensures the active client identity and clientifying power required to challenge and change the masculine pattern and understanding of entrepreneurship. The recommendations also encompass a strategic implementation of the selected components by simultaneously targeting economic, managerial and psychological effects. As concluded in the study, the primary need seems to concern business counselling methods that are able to acknowledge the structural barriers women face in organisations societies permeated by a masculine pattern and understanding of entrepreneurship, rather than for business counselling targeting women due to their gender per se. Such structural strategies would be especially suited for gender-sensitive business counselling tailored to entrepreneurship within science and technology, where the challenge is dual: to change masculine norms of entrepreneurship in general as well as of science and technology entrepreneurship in particular.

Note

1. To enable an international and scientifically qualified debate, only studies written in English and published in scientific journals, books, and reports were considered in the literature review. The only exception was Johansson (2008), which is written in Swedish and was included because of its valuable approach to the gendered relationship between the counselor and the client in business counseling.

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7

Gender, Commercialization and Thought Leadership in Computing: Examining Women's Participation in Information Technology Patenting and Conference Paper Authorship

Catherine Ashcraft and Joanne McGrath Cohoon

While a number of studies have documented the under-representation of women in computing and information technology (IT), few studies have investigated gendered patterns in IT patenting or authorship. Understanding female participation in these areas is important for helping us understand women's involvement in the recognized and rewarded aspects of IT innovation, research, and commercialization. Documenting these trends also helps us move beyond merely counting *how many* women are in computing professions and toward measuring their *meaningful participation* in the field. Toward this end, we discuss findings from two studies we have conducted on female IT patenting and female authorship of computing conference papers. In brief, we find that female participation is rather low, particularly in patenting,

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but that while progress at times may be uneven, women's participation is increasing in both arenas in promising ways. We also explore how female participation in patenting and authorship varies across organizations, sectors, and conference venues and the implications of this for fostering more female participation in these arenas. Below, we present detailed findings first from our study of female patenting, followed by our findings related to female authorship.[1] In the next section, we first situate these studies within previous research related to gender and computing

Prior Research on Gender and Computing: A Focus on Quantity

Women's low and declining participation in computer science and IT is well documented. In 2014, women received 57% of all bachelors' degrees, but only 17% of computer and information science degrees—down from 37% in 1985 (U.S. Department of Education 2014). The picture is also bleak in industry, where women's overall participation in IT professions has fallen from 37% in 1990–1991 to 25% in 2015 (U.S. Department of Labor 2015). These numbers are even more troubling when considering women of color. For example, African-American women hold only 3% and Latinas hold only 1% of these occupations. These trends also are of increasing concern given recent research demonstrating the benefits that diverse work teams bring to enhanced innovation, problem-solving, and productivity (e.g., Gratton et al. 2007; Page 2008; Woolley et al. 2010).

Fueled by the growing dismay over these trends, significant research has identified a number of key barriers to women's participation and advancement in IT. These barriers include isolation, a lack of role models, mentors, and sponsors, problems with supervisory relationships, inequitites in performance and promotion procedures, hostile work cultures, and inflexible work policies that make it difficult to manage competing responsibilities (e.g., Cheryan and Plaut 2010; Hewlett et al. 2008; Simard et al. 2008). Similarly, a number of promising reform practices for addressing these barriers have been identified and recommended (e.g., Ashcraft et al. 2016).

To date, however, this research primarily measures women's participation in computing in terms of the numbers of women recruited, retained, and advanced in computing education and careers. While these are important indicators, a focus on quantity of women in the field provides an incomplete picture. Much more information is needed in order to truly understand if and how women are able to meaningfully participate in the innovative and creative aspects of technical innovation. And, indeed, some research suggests that women in computing tend to be channeled into execution or support roles rather than into the core, creative roles. For example, one study found that nearly half of all women in technology fields reported being "pushed" into execution roles and not having equal access to creator roles (Hewlett et al. 2008). Merely increasing women's physical presence in the field will do little to foster better innovation or enhance equity unless women are also able to meaningfully contribute to the creative aspects of technical innovation.

As a result, we suggest that moving beyond a mere focus on quantity and toward an understanding of the quality of women's participation in innovation is necessary. Doing so will help us accomplish at least three important goals. First, it will help us ensure that the field actually capitalizes on the diverse perspectives women bring to technical innovation. And these benefits will extend well beyond the field of computing, since nearly all scientific and engineering innovation efforts increasingly depend on computing.

Second, because participation in innovation plays an important role in the trajectory of technical careers, understanding women's participation in this area is important for improving their career prospects and for existing efforts to advance women in computing fields. For example, the extent to which women are able to participate in innovation can either ameliorate or exacerbate existing inequalities and economic disparities as it greatly affects their ability to gain promotions, receive research and investment funding, engage in more significant research projects, accept higher status positions, and increase their personal income potential. Indeed, evidence suggests that limited access to these channels and their associated rewards may also be one reason women decide to leave IT careers (Hewlett et al. 2008). Understanding women's participation in innovation is important, then, for ensuring that innovation practices and processes do not become or remain another mechanism for perpetuating existing inequalities.

And finally, understanding how women already contribute to the field in meaningful ways has the potential to help us attract more women and girls into the field. Too much attention to the dismal trends in women's presence in technology can ultimately discourage young women from entering what they may perceive (and what often proves) to be an unwelcoming or isolating environment. Instead, documenting and showcasing the significant contributions women already make to the field and to broader society may help balance the more discouraging data and recruit more women into the field. Indeed, research has shown that role models, as well as the ability to make a difference in society, can be factors shaping girls' and women's career decisions (Cheryan et al. 2010; Guzdial et al. 2013; Lasen 2010).

Measuring Female Contributions to Technical Innovation: Expanding Our Focus to Include Quality

Toward these ends, this study aims to further our understanding of how women are participating in the creative aspects of computing innovation and thought leadership. Measuring *how women are contributing* to the field is, of course, more difficult, than merely measuring *their presence in* the field. As a result, few established metrics exist for measuring women's contributions to innovation. We suggest that examining women's participation rates in patenting and in authoring conference papers can serve as two important types of what we term "innovation metrics." While these two measures are certainly not the only possible measures of innovation, they are two readily available and relevant measures of women's participation in the rewarded aspects of technological innovation. Patenting has long been an important endeavor in industry and it grows increasingly important in academic institutions (Kenney 1986; Slaughter and Leslie 1997). For example, a number of studies demonstrate an increase in academic faculty's patenting activities over the past two decades (e.g., Kleinman and Vallas 2001; Owen-Smith 2005). Likewise, during this period of time, industry and academia have begun to participate in new and unprecedented types of collaborations, including shared research projects and licensing of patents, among others (Owen-Smith 2003). Although much more prevalent in industry, patenting also measures academic productivity and performance, particularly as universities increasingly partner with industry to pursue research. Indeed, Owen-Smith and Powell (2001) suggest that commercial involvement has become a "fault line" between academics who participate in patenting and academics who do not. The significance of this line also comes into sharper focus as links between patenting and funding become more prevalent (Ding et al. 2006).

Further research finds that in the sciences in general, men are more likely to be involved in these commercialization efforts than women. In a study of more than 4000 life science academics, male faculty patented at 2.5 times the rate of female faculty after accounting for differences in individual productivity and institutional status (Ding et al. 2006). Similarly, in a study of more than a 1000 life science academics, Bunker-Whittington and Smith-Doerr (2008) found that only 14% of these women faculty had ever patented compared to 30% of male faculty. These trends highlight the importance of understanding these dynamics if we are to foster women's advancement and opportunities to meaningfully participate in innovation and commercialization. Learning how these trends specifically play out in the field of computing will contribute significantly to our understanding of women's advancement in this field.

We are especially interested, then, in identifying gendered trends in IT patenting and how these patterns may have changed over time. Given prior research illustrating the benefits diversity brings to innovation (e.g., Page 2008), we are also particularly interested in examining the citation rates of patents developed by single-sex and mixed-sex teams. While gender diversity is certainly not the only measure of diversity, it is an important aspect, especially since research has shown that teams with more women outperform other teams on a number of measures of productivity and creativity (Gratton et al. 2007; Woolely et al. 2010). Also of note, in a study of the life sciences, female patents were more highly cited than patents produced by male teams or mixed-sex patenting teams (Bunker-Whittington and Smith-Doerr 2008). We are interested in seeing how these additional patterns play out when it comes to computing.

Like patenting, publication is an important and highly valued activity, especially in academia, where quantity and quality of publications influence promotion and tenure decisions. Academics often assess the quality of a publication by the prestige of its venue—typically a journal. However, in computing fields, where advances happen rapidly, faculty frequently judge peer-reviewed conference papers to be of more import than slow-to-reach-print journal papers. Focusing on quick dissemination of new findings makes clear the value they place on thought leadership as a hallmark of academic achievement and performance.

This study, then, takes both patenting and authorship of conference proceedings publications as important innovation metrics—that is, indicators for helping us understand the degree to which women are able to meaningfully contribute to technical innovation. In documenting current patenting and authorship rates, this study also provides a benchmark against which to measure future changes in women's patenting activities. Toward these ends, we asked the following research questions:

- What are the overall rates of IT patenting for males, females, and mixed-sex collaborations and how have these rates changed over the past three decades (from 1980 to 2010)?
- What are the differences, if any, in citation patterns for patents produced by male, female, and mixed-sex teams?
- How do patenting rates differ across organizations and across sectors?
- What are the overall rates of female authorship of conference papers and how have these changed over time?
- What are the differences, if any, across topics and kinds of conference venues?

Methods

In the first study, Ashcraft and Breitzman (2012) analyzed all U.S. IT patents granted between 1980 and 2010 by the U.S. patent office as these patents account for the overwhelming majority of IT patents issued globally. IT patents were defined as any patent that fit into the following categories: Communications and Telecommunications, Computer Hardware, Computer Peripherals, Computer Software, and Semiconductors/Solid State Devices. We restricted the patents analyzed to U.S.-invented and Japanese-invented patents as this accounts for the overwhelming majority of patents issued by the U.S. Patent Office. Here we present findings for the U.S. dataset, which included approximately 665,000 patents. Elsewhere (Ashcraft and Breitzman 2012), we also present our analysis of the Japanese-invented U.S. IT patents.

For the second study, Cohoon et al. (2010) analyzed data from over 3000 ACM-affiliated conferences, workshops, symposia, and forums held between 1966 and 2009. The data for this study were obtained by screen-scraping the proceedings for every conference in the ACM's Digital Library. The scraping started with the ACM Proceedings page, followed by each list of proceedings and each year's proceedings page for each conference. Proceedings pages were then processed by a custom script to extract author names and paper titles. The data obtained in this manner comprises 432 ACM-affiliated conferences, workshops, and symposia[2] held between 1966 and 2009. The resulting dataset represents approximately 86,000 papers, in approximately 3100 proceedings.

In both studies, we used a rigorous process for gender-matching, ultimately matching approximately 85% of patents holders and 90% of paper authors, utilizing gender-name identification software. We also conducted supplemental measures to identify gender ambiguous names. For example, in the first study we used the Social Security Administration's database records for how many boys and girls are given a name. These percentages were used to decide what percentage of patents to count as "male" and "female." (For more detail on these methods and the findings in the next section see Ashcraft and Breitzman 2012 for the first study and Cohoon et al. 2010 for the second study).

Results for Female Patenting Patterns

Women's patenting percentages are low (approximately 6%) but have increased over time (from 2% in 1980 to 8% in 2010). Determining "inventorship" of patents is complicated by the fact that inventors are most often listed alphabetically, although sometimes the lead inventor is listed first. To give the most complete and accurate picture, then, we present the percentage of patents invented by women in three different ways: (1) woman as *first* inventor, (2) patents with *at least one* female inventor, and (3) attribution of "fractional authorship." This latter method accounts for women as a *fraction* of several inventors on a single patent (e.g., 1 female and 2 male inventors would count as 1/3 female patent). From 1980 to 2010, approximately 13% of U.S.-invented IT patents have at least one female inventor. When assigning inventorship by first inventor, however, this number drops to 5.6% female. When assigning authorship fractionally, 6.1% of the U.S.-invented patents were female invented. We consider this latter figure the most accurate representation of female patenting during this time period.

Although overall patenting rates for women have been and remain quite low, the picture improves when we look at trends over time. While women account for only 6% of total U.S.-invented patents (when counting fractionally), that percentage has increased steadily from nearly 2% in 1980 to almost 8% in 2010—nearly a fourfold increase. These increases are particularly noteworthy because, during the past 20 years, the percentage of women employed in IT has remained relatively flat, even declining from a high of 37% in 1990 to 25% in 2010 (U.S. Department of Labor 1990–2010).

These increases are perhaps even more promising when considering the growth in IT patenting overall. When looking at trends over the 31-year period, overall U.S.-invented IT patenting has increased approximately tenfold since 1980 and more than doubled since 2000. The combination of the fourfold increase in the percentage of female invented patents with the tenfold increase in overall U.S.-invented IT patenting translates to a roughly 40-fold increase in U.S.-invented female IT patenting for the period. In raw numbers, this translates to an increase from 101 U.S.-invented female IT patents in 1980 to more than 4000 in 2010. These patterns hold true across industry subcategories as well.

Mixed-sex teams produce the most highly cited patents, with citation patterns 30–40% higher than the norm. High citation rates indicate that a patent contains technological information of particular importance. As a result, examining the citation rates of female-invented patents is one way of measuring their influence, importance, and potential return on investment. For example, companies with high citation rates have been shown to perform better in the stock market and have experienced increases in sales and profits (Breitzman and Narin 1999; Narin et al. 1987). Determining citation rates, however, involves more than simply counting the number of citations a particular patent has accrued. For example, older patents are likely to be more highly cited since they have had more time to accrue citations. Furthermore, average citation rates differ across technologies. A patent with 10 citations, therefore, may be very highly cited, or not very highly cited, depending on its age and technology category. In order to account for these differences, citation counts were normalized by technology and year in order to determine the "expected cite count" for patents from the same year and technology class. Dividing the citation count of a particular patent by the expected count results in a "citation index," a normalized measure of the impact of a particular patent.

The citation index can be extended beyond a single patent to a *set* of patents (i.e., all male-invented communication patents, all female-invented communication patents, or all mixed-sex team invented communication patents). In fact, applying the citation index to a set of patents tends to provide a more accurate picture since a larger patent set will dilute the effects of any outliers. The citation index for a set of patents is determined by taking the sum of the citations for that set (i.e., the sum of the citations for all male-invented communication patents) and dividing by the sum of the expected citation counts for all communication patents.

In conducting this analysis, we found that, among U.S.-invented patents, patents invented by mixed-sex teams are cited approximately 30–40% more often than patents invented by female-only or male-only teams. Controlling for size of team, however, accounts for much of this increase, suggesting that it is primarily the size of team that influences citation count. Why exactly do larger teams produce more highly cited patents? We considered a few possibilities but the answers remain unclear. We found no consistent significant relationship (using one-way ANOVAs) between the citation index and team characteristics such as self-citations, sector of organization (e.g., university, industry, non-profit), or country of organization.

We also investigated whether the originality index for patents might provide some insight. This index measures the extent to which a patent draws on a wider range of prior art or different kinds of technologies. In other words, a relatively simple or incremental invention will have a lower index than complex inventions drawing from multiple areas of technical expertize. A regression analysis, however, revealed that originality has very little explanatory power for higher citation rates once a team size is factored in. In other words, team size seems to matter more than the originality index when predicting citation rates. This result, however, might be because the originality index is a rather insensitive measure—i.e., it is primarily designed to distinguish highly original patents rather than to measure smaller differences in originality.

Further research is needed to determine exactly why larger teams produce more highly cited patents. For now, a likely explanation is the fact that during development, inventors and organizations often have an idea of whether an invention is likely to be of significant importance. Technologies that look particularly promising will attract more resources and inventors as organizations try to accelerate their development. In addition, inventors will happily join technical projects that look to be particularly promising. Similarly, it is also still possible that originality and diverse thinking do, in fact, influence citation rates but that, at this time, we do not have enough sensitive measures to capture or fully understand these relationships. Whatever the reason for increased citation rates, it appears that mixed-sex teams are responsible for more highly cited patents. This finding is a matter of some concern when considering the low percentages for mixed sex collaboration in IT patenting, to date.

Women's participation in patenting varies across companies and across sectors. Industry accounts for approximately 90% of all U.S.-invented IT patents (78% of these patents are assigned to U.S. companies while another 12% are invented by U.S.-based inventors of foreign firms such as Alcatel-Lucent, Siemens, or Philips). Individual inventors hold only about 7% of U.S. IT patents and universities hold only 2% of U.S.-invented IT patents. Even fewer patents are held by government agencies or nonprofits. Given its overwhelming share of patents, we first examine trends across organizations in industry and then follow this with an examination of interesting trends across sectors.

Women's patenting rates differ widely across companies. Our analysis revealed that in both "small patenting entities" (which we defined as those with less than 100 patents during 2006–2010), and in "large patenting entities" (those with at least 350 patents during 2006–2010), male, female and mixed-sex team patenting rates vary widely. When considering all 50 of these "small patenting entities," female rates, for the most part, ranged from 0 to 22%, with two companies as exceptions at 31 and 52%. In these same 50 companies, patenting rates for mixed-sex teams ranged from 3% to nearly 67%, with most companies falling between 30 and 50%. Thirty-seven companies exceeded a patenting rate of 20% for mixed-sex teams. All of the top 50 small patenting entities had at least some mixed-sex team invented patents (with the lowest rate at 3.3%). A total of 17 companies had no female-only-invented patents, but all of these companies had mixed-sex team patents, ranging from 27 to 67%.

In general, large patenting companies (those with more than 350 patents during 2000–2005) experienced a narrower range of female patenting but still differed dramatically. In these companies, female-only invented patenting rates typically ranged from 0.5 to 8%. Only one company had no female-only invented patents, but this company did have 21% of its patents invented by mixed-sex teams. The rates of mixed-sex invented patents ranged from approximately 11 to 28%, with 15 companies posting a rate of 20% or more.

A number of companies have also produced large *increases* in female rates of patenting in the past 5 years, with 20 companies posting more than a 20% increase in their mixed-sex or female-invented patenting rate. Computer Peripherals posts the slowest increases with a high of 14%. At the same time, the percentage of female inventorship in some companies actually decreased with 22 companies posting more than a 20% decline in mixed-sex or female-invented patent rates. Importantly, the fact that female patenting rates differ widely across companies suggests that organizational environments can substantially influence female patenting patterns. In the conclusion, we identify initial promising practices that seem to increase women's patenting.

Women's patenting patterns also differ across sectors. While industry accounts for the majority of IT patents, interesting trends emerge when comparing patterns across sectors. If we look at the overall combined category of IT patents, we see that U.S. universities have the highest percentage of female inventorship in each time period. From 2006 to 2010, 9.43% of U.S.-invented IT patents from universities were invented by women, compared to 8.21% for women in foreign-owned firms with U.S. operations, and 7.34% for women in U.S. firms. It is unclear why foreign firms with labs in the U.S. like Alcatel-Lucent or Philips or Sony would have a higher percentage of patents invented by women, but that seems to be the case in each category except for Computer Peripherals and Computer Hardware. Interestingly, in the last 5 years, the highest percentage of female inventorship occurred in the U.S. labs of foreign corporations (11.11%), followed by U.S. government labs (10.61%). U.S. universities and U.S. corporations followed with 10.12% and 9.05%, respectively. Another interesting finding occurs in the Computer Peripheral category where the sector with the highest percentage of female-invented patents is the individual inventor sector where women hold 11.28% in 2006–2010. These findings raise interesting questions for future research about the kinds of environments and conditions that foster female patenting.

Results for Female Authorship

Women's authorship increased even more substantially than patenting, from 7% in 1967 to 27% in 2009. The annual number of conference papers published by ACM as represented in our dataset grew from 149 in 1966 to 12,222 in 2008. This increase is somewhat expected, given the rapid growth and differentiation of computing as an academic field and overall growth in academic publishing. The number of authors grew even faster—from 389 to 37,944. This difference in growth rates of papers and authors is explained by the increasing prevalence of collaborative authorship. In 1966, papers had on average 2.6 authors, but by 2008, papers had on average 3.1 authors. Throughout this time, most authors of these papers were men, although women authors were increasingly prevalent in recent years. In 2008, there were approximately 2.3 male authors and 0.8 woman authors per published ACM conference paper.

The increase in female authorship averaged 0.44% points annually, with 10-year intervals finding women's share of authorship at 8% in 1968, 15% in 1978, 18% in 1988, 21% in 1998, and 25% in 2008. Our analysis also revealed that the rise in women's participation was not an artifact of newly created conferences that catered to women. Tracking a set of 64 long-standing ACM conferences[3] results in the same trend evident in the full dataset and confirms that women's authorship grew about 18 to 20% points from 1966 to 2009.

One explanation for this trend may be the increase in women's representation among potential authors as women earned more computing doctoral degrees. As women's representation in this community increased, one would expect a concomitant increase in their contributions to the intellectual life of computing. A second possible explanation is that women may have benefited disproportionately from collaboration. Each of these explanations is considered in more detail below, although of course, other explanations are also possible.

Research and publication are important activities of professionals with doctorate degrees. Therefore, it should come as little surprise to learn that the proportion of women Ph.D. recipients in Computer Science strongly correlates with women's conference authorship.[4] A substantial portion of the upward trend in publishing is accounted for by increases in women's share of doctoral degrees in computing. There is a moderately strong positive association between absolute growth in women Ph.D. graduates and paper authorship ($B = 0.76$ significant at 1%). Comparing the trends in women's Ph.D.s and authorship makes possible two key observations:

1. Growth in women's publishing rates paralleled women's doctoral degree rates. The average annual growth in women's share of ACM conference authorship was 0.44% points, compared with 0.45 points for computing doctoral degrees.
2. Women publish at higher rates than one might expect from their representation among Ph.D. holders. In 1967, women's representation among authors was about 4 points greater than among doctorate degree recipients. This over-representation persisted in most years to about the same extent and it holds for both annual and cumulative percentage of women Ph.D. holders.

To investigate further, we also analyzed the relationship between growth in the cumulative number of Ph.D.s and the number of author credits, while accounting for autocorrelation, by running regression in first differences. The results indicated that for every additional woman with a computing Ph.D., women's author credits[5] grew by 3.6. Growth was less for men; additional Ph.D.s corresponded to only 2.6 more author credits. We found no correlation between being first or subsequent author and gender. Women and men were equally likely to be first authors on the papers they wrote. These results appear to contradict well-established findings that academic men publish more than women, so it is important to recognize that there are several potential unknown factors that might affect men and women authors differently.

Women's sole authorship and collaborative authorship both increased. We investigated the possibility that more collaboration by women could contribute to their apparent productivity, and that it might help explain the upward trend in women's representation among authors. Our analyses suggest that collaboration explains little about the increase in women's share of authorship. By 2008, collaboration was most common, with 97% of all ACM conference papers written collaboratively. Throughout the years, men authored more papers solo than did women, but at about the same gender representation as seen for authors overall. The number of papers written by individual men peaked in 2006 at a little over 1300. Individual women also contributed the most papers that year—about 415, or 24% of all individually authored papers in that year. The trend toward co-authorship appears to have begun in the mid-1980s and accelerated in the late 1990s. In contrast, the trend in women's representation among ACM conference authors increased at about the same pace since the early 1970s. This observation suggests that while women may have benefited from the increasingly common practice of co-authorship, collaboration probably does not explain much of the trend toward gender parity among computing conference paper authors.

Women's share of paper authorship varies across ACM conferences. To understand if there were differences in female authorship by conference type, we calculated women's percentage of authorship in 64 long-standing ACD conferences. For each conference, we averaged the percentage of female authorship over a 10-year interval from 1998 to 2008. Women's authorship ranged from a mean of 10 to 44% women authors, with most conferences having between 17 and 29% women authors. The average percent of women authors among the 64 conferences was 23% with a standard deviation of 6%. Tables showing all the large ACM conferences with especially high or low average participation of women authors for the past 10 years are available online. We focused only on relatively large conferences, dropping conferences listing fewer than 100 authors.[6] By looking at the extremes, there may be a hint at alignment with gender stereotypes as a factor in the distribution of women authors across conferences—at the high end, the conference topics are children, education, and human computer interaction. Any potential misalignment with feminine stereotypes is less obvious at the low end. The trend over time for most (40) of these conferences was a clear upward slope in women's authorship. Several conferences (18) had neutral slopes for the trend in women's authorship. A few conferences (6) had negative slopes indicating declines in women's share of authorship over time, although these include conferences that had very high female participation to begin with. There was no obvious pattern to which of the conferences had positive, neutral, or negative slopes.

Conference topic relates to authorship overall, and to women's authorship. Thus far, the data appear to offer some support for the hypothesis that female authors might be more prevalent in conferences focused on specific topics. To further investigate this observation, we coded each conference according to its ACM-designated general topic classifications: *Algorithms, Design, Documentation, Economics, Experimentation, Human Factors, Languages, Legal Aspects, Management, Measurement, Performance, Reliability, Security, Standardization, Theory and Verification.* On face value alone, it seems reasonable to expect that the topic classifications most closely aligned with feminine stereotypes would be Human Factors, Design, and Documentation; those most closely aligned with masculine stereotypes would be Algorithms, Theory, and Security.

This analysis used a subset of the full dataset ($n = 391$ conferences): those for which we were able to obtain additional information. The data contained all the cases with publicly available information on paper acceptance rate (used as a proxy for conference prestige) as well as conference location and the ACM general classifications terms for each conference. Most of the conferences in this subset were held between 1998 and 2008, but 91 conferences dating earlier than 1998 were included to maximize the number of observations. The earliest conference included in the set was held in 1981.

Coding by conference topic shows variance in the prevalence of authors who published on certain topics. The descriptive results show that, like men, women were most likely to publish their papers in ACM conferences on Design and on Theory. Human Factors and Algorithms are the next most popular conference topics, with women much more likely than men to publish in conferences on Human Factors and men more likely than women to publish in conferences on Algorithms. The greatest gender differences were evident in conferences focused on Human Factors, Languages, Algorithms, and Performance in decreasing order.

Following up on the descriptive evidence, our final statistical analysis used Ordinary Least Squares (OLS) regression to measure factors that contribute to variation in women's percent of authors published in a conference. The results[7] show that, controlling for year, conference topic substantially predicts the gender composition of authors for a conference. Conference acceptance rate is also weakly associated with women's authorship ($B = 0.07$, Beta $= 0.14$, significant at the 0.001 level). Conferences with more papers accepted are slightly more likely for a greater share of those papers to have women authors. The "Human Factors" topic had the strongest relationship with women's share of authorship ($B = 0.049$, Beta $= 0.314$, significant at 0.001 level). Other topics that were significantly and positively correlated with the percent of women authors were Documentation, Management and Measurement (respective values of $B = 0.040$, 0.038, 0.030 and Beta $= 0.122$, 0.256, 0.192, all significant at the 0.001 level). Algorithms was the topic with the strongest negative association with women's share of authorship ($B = -0.033$, Beta $= -0.209$, significant at the 0.001 level). Other topics that had significant negative correlations with the percent of women authors were Performance and Reliability (with the respective values of $B = -0.021$, -0.036 and Beta $= -0.144$, -0.180).

These findings lend mild support to the hypothesis that alignment with gender stereotypes predicts the extent of women's authorship. As expected, conferences focused on Human Factors and on Documentation were associated with greater portions of women authors, while conferences on Algorithms were associated with greater portions of men authors. No evidence supported our hypothesis that Design, Theory, and Security would also be gender skewed, however.

Implications

These two studies provide valuable insights regarding women's increasing participation in both patenting and authorship. While the percentages are still low, especially in patenting, the good news is that the trends are positive with female participation, in many cases, outpacing the growth of the field overall. Interestingly, when it comes to female authorship, our findings illustrate that although women comprise only about 27% of computing conference paper authors, this representation is greater than in the pool of likely authors. Women's apparent productivity seems to indicate that once they obtain a Ph.D., women do not face substantial gendered barriers to contributing to this aspect of intellectual life in the field.

Whether or not the initial findings about women's disproportionate productivity in authorship holds up to further scrutiny, the results still show a clear benefit to the discipline from increasing women's representation among doctorate degree holders. The benefit is evident in the strong positive association between women Ph.D.s and women's contributions as authors. While gender balance among thought leaders in computing remains a distant goal, increasing women's educational attainment appears to move us toward that end.

Additional good news emerges in the finding that the level of female inventorship in IT is quite high at particular companies. This suggests that systemic factors, such as company environment, can make a difference. Women could continue to gain greater shares of IT invention, especially if we identify and replicate the conditions and practices that foster women's increased patenting efforts. Toward this end, we identify one promising practice with initial positive results: the development of patenting learning communities *(see call out box)*. We also call for future research to identify more of the practices that would lead to greater increases in female participation in patenting and authorship.

As noted earlier, publicizing "good news" that balances some of the more dismal statistics for women in technology is important for recruiting more women into the field. While improvement in authorship and patenting is uneven and while there is certainly room for more improvement, we suggest that these trends are promising overall. We also suggest that organizations would do well to highlight the increasing contributions women are already making to innovation as a way of recruiting and retaining more young women. Increasing women's visibility in existing commercialization, innovation, and authorship is important for demonstrating that women can and already are enjoying rewarding careers and making important contributions to computing.

Finally, these findings also raise a number of additional questions for future research. For example, as noted earlier, many questions still remain regarding the relationship between team size and increased citation rates. In addition, the patenting data alone tells us little about the reasons for the dramatic differences across organizations. As a result, future research would do well to explore how the demographic makeup and size of a company influences their female patenting rates. For example, do companies with higher female patenting rates also employ larger numbers of women from the start? What other characteristics, if any, do higher female-patenting companies share? Do specific organizational practices and conditions contribute to women's higher patenting rates and if so, in what ways? This additional research is necessary for understanding the existing variance across companies and for identifying the specific contexts and conditions that foster female participation. Future research examining some of the contradictory findings about women and men's relative productivity in authoring computing conference papers is also warranted, as is more qualitative research examining the conditions that inhibit or foster this productivity.

Finally, while we have proposed these two measures as valuable "innovation metrics," we also encourage future research that might identify additional metrics we can use to better understand *how* women are participating in computing. We also suggest future qualitative research that might enhance these more quantitative metrics and give us a more in-depth picture of women's participation in these important and highly valued aspects of the field. Expanding our focus in these ways is vital if we are to ensure that women are able to participate in thought leadership and innovation that will so significantly shape future worlds.

Notes

1. More information on some of these findings can be found in Ashcraft and Breitzman (2012) and Cohoon et al. (2010).
2. All of these events will be called "conferences" for simplicity in this paper.
3. All ACM Conferences that existed for 10 or more years.
4. Graduate students earn many of the author credits for papers in the ACM Digital Library, but their number and gender representation should be very similar that of Ph.D. recipients.
5. "Author credits" count authors each time they publish. So, we are *not* comparing degree recipients to papers published, nor to authors; instead, we compare degree recipients with instances of authorship.

6. Averaging across all the years for which we have data produced little difference compared with averaging across only the 10 most recent years; 83% of the listed conferences remained in the same categories.

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8

Fostering Collaborative Innovation: Fraunhofer's Participatory Methodology

Kathinka Best, Michael Rehberg and Martina Schraudner

Introduction

Innovation can contribute significantly to increase a firm's commercialization and profitability. However, how do highly successful innovations come about? What makes them viable? For almost two decades, practitioners and researchers have included (lead) users in innovation processes and studied "open" and "collaborative" innovation processes in an attempt to answer these questions (von Hippel 1988, 2005; Brown and

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Eisenhardt 1995; von Hippel et al. 2011). Successful knowledge search (Laursen and Salter 2006) as well as collaborative, interactive, and iterative processes have received ever-growing attention (e.g., Stolterman 2008)—with an increasing emphasis on sustainability and responsibility (von Schomberg 2013). We define user-directed, collaborative innovation processes (Oudshoorn and Pinch 2003; Priem et al. 2012) as directed both toward and by prospective consumers, "experts in the everyday" (von Hippel 1988; Chesbrough 2003).

Despite the large amount of research already undertaken (see Anderson et al. 2014, for an overview), studies on concrete collaboration processes and tools are still rare. Most of the literature on the absorption of knowledge, R&D performance, and search processes bases on indirect data and tends to neglect users' sociodemographic characteristics (such as gender, age, and nationality). This concerns both quantitative as well as qualitative studies (Fey and Birkinshaw 2005; Laursen and Salter 2006). The empirical base underlying these theoretical models is therefore considered relatively slight (e.g., Laursen and Salter 2006). The lack of concrete, scientifically evaluated tools and procedures (Anderson et al. 2014) of observational research methods focusing on the search for (external) ideas and knowledge integration (Laursen and Salter 2006), and of approaches for identifying innovation opportunities remains (e.g., Day 1994). This is especially true when considering the gender dimension, which is roughly constituted of a qualitative component (integration of gender aspects into project trajectories and cultures) and a quantitative component (i.e., the representation of women and men) (Ranga and Etzkowitz 2010; Best et al. 2016). Griffin's claim (1997) to define tools and infrastructures that best support multifunctional innovation teams *across projects and industries* is also yet to be met (Ernst 2002).

With the aim of shedding more light on the identified research gaps and keeping an eye on the responsibility in research and innovation—and the gender dimension in particular—, we expanded von Hippel's approach of including lead users (von Hippel 1988; von Hippel et al. 2011) toward including *future* respectively *potential non-lead users*. Moreover, our processes start with a societal challenge, which is to be met *before* including the user perspective, encapsulating current trends in Open Innovation as summarized by Gassmann et al. (2010), while changing the search mechanism. Our ideas on open *and* responsible innovation turned out to be in line with von Schomberg's vision of responsible research and innovation (2013). In Europe, this "participative" approach to "democratizing" innovation and commercialization (von Hippel 2005) has also received growing political attention during the last years (Owen et al. 2013; Owen et al. 2012; European Commission 2013a). That makes our approach viable and useful for *responsible* research and commercialization endeavors in the European Innovation Union.

Germany is the largest and one of the most innovative economies in Europe (European Commission 2015). Seeking to address major research fields that have received top political priority in Germany—i.e., health, sustainable economy and energy, digital economy and society, innovative workplaces, intelligent mobility, and civil security (Federal Ministry of Education and Research 2010, 2014), —we conducted the *Discover Markets* pilot study between 2010 and 2012 to test an original methodology for user-directed, collaborative research. This methodology includes collaborative ideation, novel interaction formats, and approaches for identifying innovation opportunities in the first and early stages of the innovation process. It generated a range of ideas for potential technological innovations and strategically fostered entrepreneurial activities

The research question addressed by *Discover Markets* and in this paper is: *How can we successfully integrate the knowledge of (potential) users into technology development processes? And how can we simultaneously consider the gender dimension, and successful commercialization?* To answer this question, we conducted 18 workshops with 156 participants (inter alia possible users) from a range of various functional and professional backgrounds. In line with Yin (2013) and Eisenhardt and Graebner (2007), we combined quantitative methods (data and document analysis, quantitative survey) with qualitative methods (participatory observations, key informant interviews) to explore the projects' multistaged process in depth.

This paper first presents the theoretical background that underpins the developed methodology and describes findings from innovation, organization, and gender-diversity research. We then present the project as a case study and derive five principles of user-directed innovation. Proposals on how to keep track of the gender dimension in the process and manage responsible research and development conclude in the final section.

Theory

Research on product development and innovation processes started in the 1970s and has since reached following conclusions regarding the underlying success factors, as Ernst (2002) points out: a clear, well-communicated strategy, adequate resources, senior management commitment and accountability, strategic focus, and synergies to existing markets and technologies. Nonetheless, commercialization that largely bases on high user acceptance usually was the last step to test the viability of innovative products. Recent studies that go beyond these approaches and focus on *open* innovation emphasize the role of different actors—networks, alliances, and 'innovation communities'—for innovative performance. They suggest iterative trial-and-error processes in idea generation, development and exploitation, a high openness to new ideas, and a problem-solving mindset (von Hippel 1988; Chesbrough 2003; Afuah 2003; Fey and Birkinshaw 2005). Search and integration of user knowledge also plays an ever-increasing role.

The herein addressed research question on *how we can successfully integrate the knowledge of (potential) users into technology development processes—with a focus on the gender dimension*—still lacks the integration of different perspectives, as Gassmann et al. (2010) pointed out. The authors divide current research streams on open innovation into nine different perspectives, three of which are integrated in this case study: (1) the *user perspective,* which they regard as one of the open innovations' best-researched fields. This paper focuses on *team constellations*, an angle which has received less attention in the past. This perspective is herein combined with (2) the *cultural perspective,* referring to the processes, artifacts, and mindsets influencing the innovation process, and (3) the *leveraging perspective* which refers to the opportunities emerging from an open, co-creational process in which existing research competencies and business model thinking are integrated. In order to address our research question and referring to von Schomberg's (2013) approach toward responsible innovation, we add (4) a *responsibility perspective* and analyzed recent literature to design our methods and processes of the *Discover Markets* project accordingly. The theoretical fundament is recapitulated in the following with a focus on the user/team constellation and the gender dimension.

Team Diversity and the Management of User Knowledge

(User) knowledge, which transcends conventional institutional boundaries, lies at the core of innovation processes (Nonaka 1991; Chesbrough 2003; Nooteboom et al. 2007). Consumers often even do the spadework and end up inventing and producing new products for themselves where established companies do not see a profitable market (von Hippel et al. 2011). Users, and therefore customers, are referred to as a major source of innovation (von Hippel et al. 2011). Organizations that consider knowledge and future needs as particularly crucial for successful commercialization value this customer innovation as an important production factor, which can foster their organization's own capacity for innovation (Teece et al. 1997; Priem et al. 2012). Nevertheless, even today, decision-makers cannot *fully* consider the perspectives of potential users, as users frequently produce nonvisible artifacts of knowledge and vary greatly in their acceptance of potential markets. Decision makers, therefore, miss out the knowledge needed for optimal commercialization of their products and services. In research and development, this approach is even less prevalent. The difficulties encountered in knowledge and idea management often prevent securing a competitive advantage (Laursen and Salter 2006).

Another hindrance in many organizations is that structures and resources often prevent the realization of employees' ideas (as users) so that promising innovations remain commercially neglected (Martins and Terblanche 2003). At this point, Field-Configuring-Events——FCEs—come into play, as they will often continue to provide many opportunities for "independent collaboration" —joint but autonomous realization of shared ideas (Hardy and Maguire 2010). They will be depicted in more detail as they diminish several hindrances to diversity and the importance of (gendered) user backgrounds will be considered in more depth as well.

User and Demand Perspective

What is the right degree of diversity in the knowledge base of participants involved in an innovation process? The *theoretical answer* to this question consists of (cognitive, organizational, social, institutional, and geographical) proximity dimensions of knowledge (Boschma 2005) and empirical notions of structural holes and network effects (Ahuja 2000; Burt 2004): The diversity of participants' social and professional backgrounds lead to *knowledge gaps*. In particular, *knowledge bases* which somewhat overlap but primarily complement and possibly increase innovativeness. Their utilization in the co-creation process can foster both individual and mutual creativity (Boschma 2005). Beyond the theoretical foundation for utilization of diversity and its benefits, in practice the major driver for companies to increase and manage diversity is the expectation of a better commercialization of products and services (e.g., Ely and Thomas 2001).

The inclusion of both men and women, in particular, secures access to different life realities, both gender-specific and otherwise. Research findings indicate, for instance, that gender-mixed teams, as compared to homogeneous teams, exhibit higher analytical effectiveness and produce nontrivial solutions (Woolley et al. 2010; Bear and Woolley 2011). According to the critical mass theory (Kanter 1977), either men or women should account for at least 30% of any working group. Simultaneously, many research and development projects taking place at various research institutions across the U.S.A. and Europe only partly meet this requirement (Ranga and Etzkowitz 2010; Ranga et al. 2012; European Commission 2013b; Best et al. 2013). As a result, substantially fewer women than men contribute to the identification of prospective research and development trajectories (Busolt and Kugele 2009;

Bührer and Schraudner 2010; Etzkowitz et al. 2007). Initiatives such as Gendered Innovations, jointly conducted by Stanford University and the European Commission, established that research and development conventionally and consequently considered human diversity only to a minimal degree. The research and development of certain common products such as seatbelts, knee prostheses, or medical products, for example, did not fully take human diversity into account and disregarded physical differences between men and women in particular—inducing disadvantages for women (Schiebinger 2008; European Commission 2013b).

However, according to Nooteboom et al. (2007), there is a "trade-off to be made between the opportunity of novelty value and the risk of misunderstanding" (Nooteboom et al., Research Policy 36:1030, 2007). It is the tipping point of heterogeneous versus homogenous groups: (Gender) diverse teams are more prone to conflicts, mistrust, lower cohesion, and lack of sensitivity which can negatively affect their function, performance, and information exchange (Cox and Blake 1991; Williams and O'Reilly 1998; Gratton et al. 2007; Østergaard et al. 2011). In addition, higher heterogeneity alone does not automatically lead to a higher level of creative output (Somech and Drach-Zahavy 2013). This concerns demographic diversity as much as functional heterogeneity, i.e., differences in skills, knowledge, and experience (Williams and O'Reilly 1998), and more latent, qualitative attributes of diverse teams such as interaction patterns (Harrison and Klein 2007). At the same time, research indicates that the *quality of interaction* is often more crucial to team performance than "mere" diversity of its members or the degree of their individual intelligence and expertize (Woolley et al. 2008). More complex research trajectories, therefore, require both wider knowledge bases and a better *interaction management* (Nooteboom et al. 2007; Nickerson et al. 2004). Processes and methods that enable mutual understanding (Page 2007) and leverage "tacit knowledge" of diverse and in particular gender-mixed teams (Nonaka 1991, "tacit knowledge" refers to the insights and intuitions that come from individual experiences and role perceptions) were therefore the focus of our collaborative processes.

Cultural Perspective

Several meta-studies indicate that the "right" organizational culture is key to secure competitive advantage and capture the benefits of diverse teams (Kochan et al. 2003; Horwitz and Horwitz 2007; Joshi and Roh 2009). The required organizational culture values and accommodates difference (Cox 2001), is open to risk and change, promotes trust and open communication, and has high tolerance for mistakes and conflicts (Ahmed 1998; Martins and Terblanche 2003; Khazanchi et al. 2007; Boyer 2007). By additionally promoting continuous learning and "participative safety"—defined as a team atmosphere experienced as supportive, non-threatening, and trustworthy together with the opportunity to participate in decision-making (Somech and Drach-Zahavy 2013)—cultures can enable individuals to explore and communicate their needs and preferences. Such cultures thereby significantly increase knowledge exchange and integration, as well as individual learning capacities (Cohen and Levinthal 1990; Nooteboom et al. 2007; Gratton et al. 2007). This is true for gender-mixed groups in particular (Acker 1990; von Stebut and Wimbauer 2003; Corley and Gaughan 2005; Achatz et al. 2010). They allow individuals to find a "common cognitive ground" for combining their "tacit" and "explicit" knowledge and to externalize it in the form of innovative realities (Nonaka and Takeuchi 1995).

How does one apply this knowledge in a collaborative approach to research and innovation processes? Suitable interaction formats, including a range of innovative ones, are required. Project and network structures might be more capable of realizing this goal compared to "conventional" organizational structures (Burt 2004; Ahuja 2000). Defined as *temporary social organizations*, *Field-Configuring Events,* or FCEs[1], such as conferences and trade fairs, might be especially effective in fostering innovation. Their culture is *independent* of organizational cultures and offers more room for experimentation. By erasing social and professional boundaries, FCEs possibly foster "participative safety" and interaction on equal terms. Collaborative processes and methods should allow for such formats (e.g., workshops) and cultures to enhance the integration of user-knowledge in the innovation process—especially input from females.

Leverage, Responsibility For, and Viability of Knowledge

The question on *the right degree and utilization of diversity in the innovation process* has been addressed in the previous section. Another important question is *at what stage should users be involved in an innovation process?* The opportunity to both develop and realize one's own ideas can, moreover, substantially foster innovative behavior and increase personal accountability (Martins and Terblanche 2003; Ketchen et al. 2007). Leverage—in the form of entrepreneurial activity—should therefore be part of a successful innovation process, especially in turbulent markets with a high ambiguity about user needs (Shah and Tripsas 2007). Larger responsibility in the innovation process, as defined by the European Union's RRI approach, furthermore implies a greater viability of knowledge in form of successful commercialization.

Leverage Perspective

Research on strategic entrepreneurship indicates a higher level of innovativeness when employees or participants of an innovation process can realize their own ideas. Ketchen et al. (2007) defined strategic entrepreneurship as "the pursuit of superior performance via simultaneous opportunity-seeking and advantage-seeking activities" (Ketchen et al. 2007, 371). In the same vein, Shah and Tripsas (2007) demonstrate that a large fraction of users innovate the areas of industrial and consumer products—sometimes in a more radical manner than companies do. According to their model of the "end-user entrepreneurial process" (Shah and Tripsas 2007, 129), the diversity of user backgrounds does not only help in solution testing. The diversity of user backgrounds is best used in the early stages of the innovation process. Going beyond von Hippel (von Hippel 1988, 2005; von Hippel et al. 2011), the authors hypothesize that the identification of user's unmet needs, user experiments, and their sharing of novel solutions *before* (a firm's) opportunity identification is key. In line with this hypothesis, Gassmann et al. (2010) emphasize the importance of alliances in the process and of the role of research organizations as knowledge brokers, with shared rights for commercialization between the involved players. Research, moreover, shows that women regard financial insecurity as a hindrance to own entrepreneurial activity much more frequently than men do (Truebswetter et al. 2015). This point will be taken into account during our user-centered process.

Responsibility Perspective

The aim of the pilot *Discover Markets* was not only to create innovations that are viable but also to further comply with self-set standards regarding sustainability and responsibility. With this goal in mind, and before the European Commission published its RRI Framework (European Commission 2012), the authors wanted to test an innovation process that adheres to fundamental human rights, ethical standards, and is oriented toward public preferences. Following Edler and Georghiou (2007) and thinking from the demand side of innovation, the authors regard knowledge—including societal needs and users' implicit needs in particular—as capital. Knowing how to commercialize it can secure a substantial competitive advantage.

When *Discover Markets* started in 2010, diversity and especially the gender dimension was—and continues to be—partly neglected in research and innovation processes (see example of Gendered Innovations, previous section). Even if women participate in research processes, they are less frequently integrated in crucial endeavors, in (in)formal networks, and patenting. Female researchers experience resource restrictions (financial and human resources) much more frequently in comparison to their male peers. Parenthood remains another large barrier (Klofsten and Jones-Evans 2000; Marlow and Patton 2005; Thursby and Thursby 2005; Corley and Gaughan 2005; Ding et al. 2006; Achatz et al. 2009; Redien-Collot 2009; Schubert and Engelage 2011). Overall and as described, the gender dimension is therefore not yet integrated into research and innovation—and hence being neglected in commercialization (Ranga and Etzkowitz 2010; Best et al. 2016).

The *six key principles* of the European Commission's Framework for Responsible Research and Innovation (RRI, European Commission

2013a) consider interalia this fact and establish standards for *responsible* processes. These are (1) Gender equality, (2) *Engagement* of all relevant social groups and enabling their collaboration, (3) *Education* of relevant societal actors, (4) *Open Access* to results, (5) *Ethics*, defined as "societal relevance and acceptability of research and innovation outcomes", and (6) *Governance* of policymakers. Including and enabling relevant and diverse groups at an early stage (von Hippel 1988, 2005; Chesbrough 2003; European Commission 2013a) —from our point of view at best *before starting the actual innovation process*—can thereby achieve even wider ranges of access to knowledge. Due to the circumstances described above, we regard "gendered responsibility" as particularly important.

Discover Markets

The essential qualities of collaborative processes directed towards responsible innovation substantially differ from traditional research and innovation processes, as depicted. Recalling the research question—*how can we successfully integrate the knowledge of (potential) users into technology development processes—and consider the gender dimension, with a special focus on commercialization?—Discover Markets* is described in the following.

Fraunhofer, one of the largest applied research organizations in Europe, has long been working on nonuser-centered innovation processes. Funded by the German Federal Ministry of Education and Research, BMBF, and conducted between 2010 and 2013, Fraunhofer's *Discover Markets* developed an original methodology that promoted knowledge transfer and enabled users to codefine the long-term trajectories of scientific and technological advances. At the core of the developed method lies a multistaged, co-ideational process that is centered on the users "lay" input, and is further conceptualized, moderated, and evaluated by engineers, social scientists, and professional creators such as designers. Over the course of the project, this process was conducted multiple times in 18 workshops and resulted in 156 participants jointly developing 755 original suggestions, primarily for the fields of energy, environment, climate change, and of health and nutrition. Some of the developed ideas resulted in successful follow-up projects with a funding scope of approximately 3.5 million Euros.

Going beyond traditional research and innovation processes, co-design and design thinking methods supplemented the traditional model of the innovation process (e.g., Brown 2008; Martin 2009; Lockwood 2010). Keeping an eye on entrepreneurial activities and highly marketable products, *Discover Markets* consisted of (different, continuously improved versions of) an iterative, multistep procedure. It bases on Design Thinking principles such as openness and "visual thinking" (Arnheim 1969) and the principle of generating "added value" by offering a unique user experience (De Chernatony et al. 2000). Participating teams were both functional and transdisciplinary (in line with Brown 2008).

The *Discover Markets* process consists of five phases: (1) *market definition*, including research and expert interviews, (2) *ideation, condensing and refinement*, including participative observation of users in the project environment, (3) *evaluation,* (4) *prototyping of ideas,* and (5) *business models*—a relatively direct path to commercialization. This process substantially differentiates the project from Design Thinking processes in the way that thinking spaces *enable users* to innovate in an artificial project setting.

Research Design and Data Collection

The evaluation of *Discover Markets* took more than 2 years. Several workshops were conducted and several research methods were combined.

Research Design

In order to explore the natural setting, context, and complexity of the entire *Discover Markets*' multistaged process and its original methodology, we applied theoretical sampling (Eisenhardt and Graebner 2007) and evaluated two of the *Discover Markets*' workshop series with regard

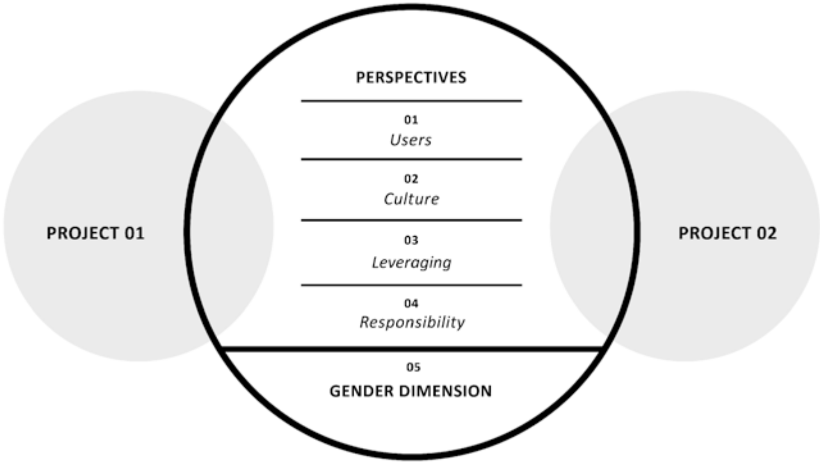

Fig. 8.1 The case study of *Discover Markets* and its structure

to the research question in form of a case study (Yin 2013). The authors opted for a qualitative case study as it is suitable for exploring a subject with unclear boundaries between a phenomenon and its context (Eisenhardt and Graebner 2007; Yin 2013). The qualitative evaluation is structured along the four perspectives: the user, cultural, leveraging, and responsibility perspective. The only category lying across these four perspectives is the gender dimension. The case study examines the ideation (step 2) and prototyping (step 4) phases, as researchers respectively entrepreneurs alone conducted the other phases. Figure 8.1 presents the case study and its structure.

Data Collection and Evaluation

The collected data included the workshops' results, participatory observations, participants' quantitative feedback, and key informant interviews. We collected data at different points in time.

1. *Documentation of results:* All 755 ideas generated were documented within the workshop in the form of "idea books." They were clustered along different application scenarios. This acted as a basis for feasibility assessments by Fraunhofer engineers.

2. *Reflexivity journals:* All analyzed workshops were accompanied and observed by at least seven researchers. All researchers moderately participated in the workshops by explaining the applied methods and facilitating the discussion with neutral questions. The notes of their observations were structured along the four analyzed perspectives (in line with Jorgensen 2015).
3. *A quantitative survey* of all participants of the workshops provided additional information. It was conducted 1–4 months after the workshops took place. The survey was conducted online from July 2012 to October 2012. Of the 156 workshop participants, 142 agreed to be contacted by email. The questions concerned the motivation for participation, expectations toward and satisfaction with the participation, impact on private and professional networks, an assessment of methods and generated ideas, as well as general opinions. Its main purpose was to analyze the degree of knowledge integration with a focus on gender. The questionnaire concluded with sociodemographic data.
   We mostly used 5-point Likert scales. The descriptive evaluation was conducted with SPSS. With an overall participation of $N = 52$, the response rate was 36.6% (measured against the total number of contacted persons); one-third of the respondents were women and two-thirds were men, reflecting the gender mix within the workshops. The average age was 43, ranging from 19 to 72 years. The respondents were trans- and interdisciplinary as the workshop participants.
4. *Qualitative interviews:* 12 qualitative *key informant interviews* were conducted (Kumar et al. 1993). The purpose of the interviews was to access a range of individual perceptions and reality constructs (Lamnek 2008) with regard to our research question. In order to compensate for liabilities of newness, which refer to the higher risk of failure for new organizations (Bruederl and Schuessler 1990), or, in our case, ideas and follow-up projects, the interviews were conducted between June 2014 and July 2014, 18 months after the workshops took place. The group of interviewees included representatives of all participating user groups, ages, and genders (Gläser and Laudel 2010). Based on our literature review and evaluation of project results, we “deductively derived” (Mayring 2010) a semi-structured

questionnaire (Gläser and Laudel 2010), which provided a framework for the interviewees' observations (Mayring 2010). In particular, the questions addressed the workshops' design, content, atmosphere, the quality of interaction, opportunities to exchange knowledge, establish new contacts, and realize one's own ideas. Each interview lasted for approximately 60 min and interviewees were encouraged to speak freely and at length (Lamnek 2008). Interview records were transcribed and coded by two researchers in order to ensure the reliability of the data. By "contextually structuring" the data and by inductively restructuring and expanding the deducted categories (Mayring 2010, 83), we established common patterns in interviewees' opinions. Theoretical saturation occurred.

Findings

Participants were divided into working groups, which deliberately included a mix of gender, age, social, and professional backgrounds. For all these four diversity dimensions, the intension was that several subgroups (the 'younger' and 'experienced', women and men, etc.) would be represented in an adequate proportion of at least 30%. This is the "critical mass" for being not perceived as a minority (Kanter 1977).

The findings of our case study indicate that *Discover Markets* promoted collaborative ideation and creation, and that its method can help foster innovation and the development of technological products in particular. The hereafter presented findings result from our quantitative survey combined with interview data and participant observation, and is backed up by measurable results such as the quantity of ideas generated within *Discover Markets*, and realized follow-up projects.

According to the main principle of qualitative research, the presented results of the qualitative interviews do not claim validity because of quantitative representativeness, but rather by illustrating typical characteristics (Haas and Scheibelhofer 1998). The authors indicate details on the respective workshop series and the gender of the interviewee after each quote. The following sections present general findings and findings in relation to each of the four "perspectives" on user-centered, collaborative innovation processes, namely the user, cultural, leveraging, and responsibility perspectives.

General Findings with a Focus on Gender Differences

The survey data suggests that participants were very satisfied and that their expectations have been fulfilled (median 4.1, 5-point Likert scale; 5 = very satisfied; $N = 52$). In line with research results on career motivation, workshop participation of women was mostly motivated by content-related interest in research topics, whereas men were most frequently attracted based on their 'interpersonal' expectation to obtain impulses for their own work and to amplify their network (Ragins 1989; Eagly and Mladinic 1994; Acker 1990).

The polled participants found both the methodological setting and the trans- and interdisciplinary nature of teams "very attractive". Participants regarded the integration of varied perspectives and competencies into the research process—by connecting actors with very different backgrounds and by utilizing original design methods—as the two largest advantages of the idea generation process. *Most interviewees* stated additionally that the multistaged design of the working process substantially promoted the production and refinement of original ideas. More than half of the survey participants experienced an innovative impulse for their work and experienced good or very good network opportunities. Interestingly, women were more satisfied with insights into research topics, and network opportunities (means: 4.1, 4.0, ad 5.0) compared to their male counterparts (mean: 3.1, 3.0, and 2.8). Many mentioned that the project inspired them to realize their own product ideas in some entrepreneurial form, especially professional creators who stated their intention for further collaborations in the future. We discuss more specific (gendered) findings in light of the four framing perspectives.

User Perspective: Knowledge Base and Interaction Management

According to the interviews, questionnaires, and research journals, participants were able to observe high levels of motivation and satisfaction, both their own and those of other participants, and for both women and men. This is already notable fact, as female researchers oftentimes reported to have been excluded from or marginalized in research processes and hence contributed less compared to their male counterparts (e.g., Achatz et al. 2009; Ranga and Etzkowitz 2010).

The quantitative survey revealed that most respondents perceived team diversity as beneficial or very beneficial for the outcome of the process (measured in terms of quantity and quality of ideas generated). Participants rated functional diversity highest (5-point Likert scale; 1 = very useful, 5 = not useful at all; mean: 1.2), followed by gender (mean: 1.43), age (mean: 1.48), and cultural diversity (mean: 1.55). The data revealed the highest correlation between the appreciation of gender mixed and interdisciplinary groups (Kendall's Tau .525; $p < 0.001$). The following interview quote exemplifies participants' positive perception of diverse backgrounds and ideas:

> Well, my impression was that we just welcomed any idea […]. And all these ideas were so different; everyone came up with something of her or his own, all by themselves. (energy workshop, woman)

Our observatory notes revealed that professional creators participated in a dual capacity—as representatives of one particular group of potential users and in their key role of process moderators. By acting in this latter capacity, professional creators substantially fostered the co-ideational process. A typical statement on the team constellation features this perception:

> Some [engineers] were already, let's put it this way, crazy in a good way […]. Others needed to be shaken a little. Either they stuck to their scientific jargon too much, as the others just sat there baffled, so there was this huge "terminology and knowledge barrier". Or they just could not leave the habitual path […]. And to make them get past it […], that's what the professional creators did, most of the times […]. Till the engineers then had their "oh, oh, I see!" moment. (health workshop, man)

Both male and female interviewees perceived collaboration between engineers and potential users as highly productive. Our participatory methods and creators helped overcome inevitable terminology and "cultural" barriers. Participation was best in small groups with less than seven participants, particularly due to women's larger contribution to discussions.

Cultural Perspective

Discover Markets established an "opportunity culture" seeking to realize the benefits of diversity by adhering to specific interaction principles, such as communication on equal terms, high failure and error acceptance, and appreciation of all "raw" ideas mentioned by implementing the projects' original methods. *All* interviewees reported that they felt accepted, extremely comfortable, and highly motivated during workshop sessions. They all perceived the co-ideational sessions as "open" and "respectful", as the following quote underlines:

> I found that everyone treated each other with a lot of respect. It wasn't […] that the most … eloquent or … yes, confident just automatically took over the discussion. No, it was a very egalitarian discussion. (energy workshop, man)

Interviewees regarded the sessions as highly professional, creativity-fostering, highly productive, and as uniting them over a common goal. To describe their experience, interviewees most often used words such as "fun," "curiosity," and "knowledge exchange.":

> What was important was that we all agreed: nothing gets rejected, period. And those who didn't like this or that idea, they would ask themselves, okay, what needs to be done differently so that it can still be realized. And so it got to be very creative, a very intense discussion. (health workshop, man)

Our methods—integrating, interalia, cocreational, and Design Thinking elements—intended to help participants overcome communication barriers and gendered substructures (formal and informal ones, in the sense of Acker 2006), to best articulate their preferences, and to strike the balance between the common sense and the scientific approach. Most interviews and survey feedback indicated that these goals were achieved. All interviewees reported, for instance, that they deliberately avoided "fixing" certain groups or conforming to certain norms and values, which often leads to reducing rather than utilizing diversity (Acker 1990; Thomas and Ely 1996).

However, while many interviewees found it easy to engage in co-ideation, male engineers, in particular, found it difficult to restrain themselves from purely practical considerations. Female participants and participants with a lower academic education were most ready to take initiative in smaller groups with a high proportion of participants with professional moderation skills. Observations indicated a level of overall high participative safety (Drach-Zahavy and Somech 2001; Somech and Drach-Zahavy 2013).

Leverage Perspective

We created the *Discover Markets* workshops to provide temporary social spaces (Lampel and Meyer 2008). The workshops served as *platforms* for individuals with very different functional and social backgrounds. They resulted in a number of ideas in which particularly male participants saw a high market potential and opportunities for follow-up projects. All interviewees perceived this prospect as highly motivating:

> Just to imagine, to be the one who develops these products or to work with those who do, was very motivating […]. It is also such an incentive when others develop some innovation that one wants to see developed, and then it's also one's idea that contributes to that. (energy workshop, woman)

Significant gender differences became evident in the quantitative survey regarding the workshops' leverage in terms of induced networks and follow-up projects. Women rated the effects of their workshop participation on their professional network in terms of follow-up (research) projects as higher; and, interestingly, more women (44%, compared to 36% of male participants) stated that the workshop inspired them to initiate at least one follow-up project. Participants' interest in a cooperation with another workshop connection (37%) —and *not* the jointly developed ideas—triggered most frequently further collaboration (in line with Lampel and Meyer 2008; no significant difference between genders). The majority appreciated new contacts and relationships outside of their usual social and professional circles. The top three reasons for not having realized projects were (1) no fit with job profile (25.6%), (2) no sufficient financial means to realize ideas (21%; only men), and (3) no adequate partner for realization (14%, no gender difference).

Responsibility Perspective

One key characteristic of the developed methodology is that each new research and development project begins with the identification of an unfulfilled public need. Participants, therefore, knew the topic and agenda of the workshop when they were invited. *To what extent was this idea of responsible innovation attractive to women and men?* More female than male participants opted for the workshops based on their content-related interest (in line with Acker 1990); the opportunity to explore and potentially accommodate the needs of a larger group of society inspired and motivated more women than men to contribute within the workshops (in line with entrepreneurial research). Participation in the *responsible* innovation process created, however, high levels of motivation and satisfaction among *all* participants. These are important drivers of innovative behavior (Martins and Terblanche 2003; Somech and Drach-Zahavy 2013). Two quotes indicate the described positive identification effect:

> Especially because it is such a huge issue, energy. I really had no idea, […] one practically had a revelation … an epiphany even… how much energy can be saved in a society! I perceived this as […] very motivating! (energy workshop, woman)

> The environment and such, the interest was huge, that was my impression. People seemed to be giving it a lot of thought, yes. (health workshop, man)

Interestingly and simultaneously, male participants realized more follow-up projects compared to participating women, especially projects that focused on addressing societal needs. From a responsibility perspective, the inclusion of gender-mixed groups in the idea generation process before realization of projects was, therefore, crucial for taking gender-specific and other differences into account (in line with European Commission 2012). Possibly, it was even more important for triggering such a high interest in products and services with a societal impact among male participants, who are normally more interested in nonsocial businesses (Shaw and Carter 2007).

Discussion

Discover Markets represents a particular approach to user-directed innovation, one that sought to expand the realm of the social and technological possibilities. This paper sheds light on the process by integrating four different perspectives on open innovation, as suggested by Gassmann et al. (2010), and the gender dimension as cross category. Figure 8.2 depicts our proceeding.

What is the most important result of the joint evaluation and integration of these four perspectives? Presented findings indicate that collaborative innovation processes—such as *Discover Markets*—require a systematic approach for a good integration of user knowledge, in particularly of women's knowledge. No such approach has existed

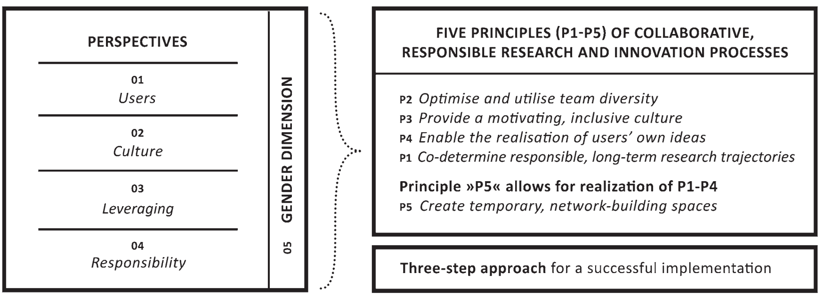

Fig. 8.2 Perspectives and recommendations of case study

previously (e.g., Fey and Birkinshaw 2005; Laursen and Salter 2006). Seeking to fill this gap, we postulate *five major principles* for designing collaborative research and innovation projects that synchronize scientific and technological advances in a *responsible* manner with social developments and help promote public interest in such advances:

1. *Co-determine responsible, long-term research trajectories,* aligned to users' needs, including women's needs and perspectives in particular,
2. *Optimize and utilize team diversity*—and especially the gender mix—with the help of co-design methods,
3. *Provide a motivating, inclusive culture,* open to risk and mistakes.
4. *Create temporary, network-building spaces*, and
5. *Enable the realization of users' own ideas* in form of intra- and entrepreneurial activity.

Given the outlined research analysis and our findings on how attracting and engaging women in the innovation process worked, we further developed a crucial *three-step approach for a successful implementation:*

First, the initial estimates on potential, broad-ranged topics that would determine the choice of participants and working formats for each workshop stream turned out to be particularly important to attract female participants to the process. In their current form, they address the four following parameters based on a predetermined research question:

1. *Need*—to what degree might a certain need be more of an *individual* or of a *societal* nature? We only realized projects addressing needs of a larger societal group.
2. *Technology*—which technological products might fulfil this need? Relatively new, *undefined technologies* bear higher success.
3. *Application areas*—what broad or narrow applications might these technologies have? Depending on the assessment, we invited specialists and generalists in different proportions to participate.
4. *User groups*—who might be the prospective users of these technologies; how broad might their range be, and to what degree might potential user groups be *defined* at this stage?

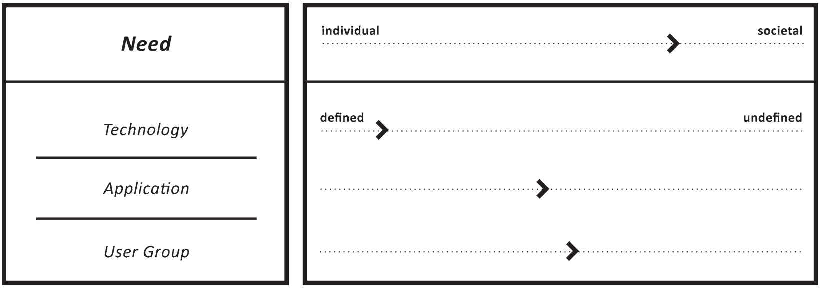

Fig. 8.3 Parameters addressed by *Discover Market's* initial estimates, an example

We mapped these estimates as shown in Fig. 8.3 and used them to identify potential themes, participants, and projects. Interaction formats based on these initial estimates were then originated and utilized accordingly.

Second, our research group established a collective, co-ideational process with an egalitarian and encouraging working atmosphere, enabling participants' potential for innovation (Ahmed 1998; Nonaka 1991; Martins and Terblanche 2003; Somech and Drach-Zahavy 2013). It is particularly important to completely include women with all their needs and preferences in such processes (Acker 1990; von Stebut and Wimbauer 2003; Corley and Gaughan 2005; Achatz et al. 2010; Ranga and Etzkowitz 2010). The implemented methods included, but were not limited to specific approaches of participatory design such as storytelling (Gottschall 2012) and design prototyping (Grand and Wiedmer 2010), visualization and prototyping of ideas (Plattner et al. 2012), and further original approaches (Heidingsfelder et al. 2015). They helped achieve cross-categorization (Gratton et al. 2007), prevent the formation of (gender-specific) subgroups (Nooteboom et al. 2007; Pearsall et al. 2008) and, ultimately, optimize collaboration and creative output in each group.

Third, the different stages of *Discover Markets* (markets, ideas, evaluation, and prototyping of ideas, business models) had clear boundaries, which enabled participants to develop creative, "silly," and "dumb" ideas without any reference to practical limitations. Participating scientists and engineers were emotionally detached from the ideas that they evaluated and prevented coalition thinking, which usually leads to less account for women's ideas (Ranga et al. 2008). The boundaries of ideation, evaluation, and Design Thinking elements (Martin 2009) substantially contributed to establishing a culture of "participative safety" and "opportunity thinking" (Drach-Zahavy and Somech 2001). Again, our findings revealed that the interaction on equal terms was particularly important to the polled and interviewed women and participants with lower academic/educational backgrounds. They benefited most from the positive working atmosphere.

Summary and Outlook

The role of public input in the innovation process continues to grow. Concerning the choice of research trajectories, research findings, and potential consequences, decision makers from politics and research increasingly regard the scientific community as accountable to the public. By including laypersons in early stages of the innovation process, particularly as representatives of the public in general and of certain social or professional groups in particular, the scientific community can best fulfil this responsibility—especially, when women are represented and included to a larger extent than they usually are (Schraudner and Wehking 2012; von Schomberg 2013). Until now, however, very few laypersons and even fewer women than men have been given the opportunity to contribute to such innovation processes.

In order to demonstrate our method, we presented a case study (Yin 2013) of two workshop series conducted within the project. Our method included (1) criteria that determined the choice of participants and working formats, (2) the crucial three steps of a user-centered development process, and (3) original interaction formats and settings including workshops and a range of proprietary creativity-fostering techniques. In accordance with Eisenhardt and Graebner (2007) and Yin (2013), our case study included a literature review, project data evaluation, participant observations, a quantitative survey, and key informant interviews.

The case study established that the *five guiding principles of user-directed innovation* help optimize the integration of participants' knowledge in innovation process with a focus on gender dimension and women, in all the variety of their perspectives—both gender-specific and otherwise (Cohen and Levinthal 1990; Drach-Zahavy and Somech 2001; Nooteboom et al. 2007; Pearsall et al. 2008; Somech and Drach-Zahavy 2013). Our research group applied the developed approach in different research fields and industry sectors, which resulted in a range of collaborative follow-up projects. One of these projects, *MyRehab*, provided a postclinical opportunity for consistent, interactive, and mobile physical therapy by motivating regular exercise and preventing health-related problems. Other follow-up projects include UBERBLIK, a platform for online collaboration, and mobile modular houses incorporating energy-saving solutions (*MoreThanShelters*). All follow-up projects based on the user-directed ideas were generated within *Discover Markets* and their commercialization benefitted from high user acceptance.

In the same vein but larger scope, synchronization of long-term research trajectories with public preferences requires a systematic method that can enable people to think in terms of societal and technological co-evolution (Jørgensen et al. 2009) and to anticipate their future needs and wants. *Discover Markets* demonstrated how such synchronization can be achieved and how it further played a role in identifying a range of potential new markets. By promoting scientific and technological advances to the public, any industrial nation can foster its economic and innovative strength. With regard to a higher integration of the gender dimension, and of women in particular, the deduced insights in gender differences regarding (1) responsibility-based sourcing and attraction, (2) content- and network-related satisfaction, and (3) inspiration for and realization of follow-up projects could be a promising starting point for further analyses. Quantitative surveys comparing male with female researchers' motivations for research projects and entrepreneurial activity could shed light on the urging question on how to even better induce impulses and create long-lasting networks to keep women's ideas in the process (apart from work-life-balance issues, see Wynarczyk and Renner 2006). Promising research exists (e.g., Wynarczyk 2007; Wynarczyk 2010, 2013); current and broad cross-country surveys are missing. Other practical options—e.g., gender-mixed idea-reshaping FCEs—are needed to be explored regarding their potential for gender-mixed coalition building. How the developed methodology can be adjusted to the specifics of more complex aims and settings remains to be established by future research, as well.

Note

1. FCEs "encapsulate and shape the development of professions, technologies, markets, and industries […] [and] are occasions for information exchange and collective sense-making" (Lampel and Meyer 2008, 1026–1027).

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9

Case Study: Hertha Ayrton

Patricia Fara

Article

Glass ceilings, leaky pipelines—these technological metaphors are often used to describe the obstacles facing women who strive to reach the top levels of science. For Hertha Ayrton (1854–1923), the image of a brick wall seems more appropriate. Despite her Cambridge education, despite years of university research, despite writing a book on electric lighting that won her the Royal Society's prestigious Hughes Medal for original discoveries, her career petered out into obscurity.

To many of her contemporaries, it seemed that little progress had been made since the publication in 1792 of Mary Wollstonecraft's *A Vindication of the Rights of Women*. Although now seen as the founding manifesto of feminism, this book argued that women should study in order to become better wives and mothers. The traditional view that a

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woman's place lies in the home was scientifically endorsed by Charles Darwin in his *The Descent of Man* of 1871. Influentially, he argued that the processes of sexual selection had resulted in the divergence between intellectually superior males and intuitive, empathetic females. His authority vindicated the opposition to female independence voiced not only by conservative thinkers but also by many who regarded themselves as progressive. Even H.G. Wells, a staunch advocate of socialist egalitarianism, dreamt of a utopian future characterized by an "ideal of a virtual equality, an equality of spirit." In his modernist vision of 1905, mothers would be paid achievement-based salaries not for professional careers, but for fulfilling their major responsibility: rearing large numbers of healthy, intelligent children to improve the British nation.[1]

"I do not agree with sex being brought into science at all," Ayrton told a *Daily News* journalist in 1919; "The idea of 'woman and science' is completely irrelevant. Either a woman is a good scientist, or she is not."[2] A fine objective, yet even now, a hundred years later, relatively few women reach the upper echelons of scientific career structures. Many initiatives have been launched to understand and hence to address that gender imbalance. One approach is to explore women's historical participation in science: being aware of how discriminatory attitudes existed in the past and still survive today is essential if they are to be eradicated.

History is exciting and challenging because it entails interpretation as well as discovering facts. Yet, as a consequence, individual authors can have great effects on how a person is perceived. This has been particularly detrimental for female scientists, because whereas biographers often describe a man's life in terms of his career and achievements, for a woman they tend to emphasize family relationships and character. Moreover, whereas surnames are routinely used for a male subject, many biographers follow the patronizing custom of calling women by their first name. Ayrton herself knew the damage that can be caused by bias. She was a close friend of Marie Curie, and when she heard that the younger scientist's discovery of radium had been wrongly attributed to her husband Pierre, she declared: "Errors are notoriously hard to kill, but an error that ascribes to a man what was actually the work of a woman has more lives than a cat."[3]

This article is intended to be not a biography of Ayrton, but a route to appreciating how the life of a woman who was active over a century ago can still be relevant today. By presenting her story in two different ways—first as a success and then as a failure—I emphasize how her gender affected both her career and her reputation. Deliberately exaggerated—but not falsified—these two contrasting views of Ayrton illustrate implicitly how a woman's status is affected by how she is described. Ayrton appears first in the guise of a typical scientific heroine—the romanticized tale of a mythical icon rather than a real person—and then as an outsider who was constantly struggling to enter a male-dominated realm.

Hertha Ayrton: Beautiful Genius

One of Hertha's fellow students remembered her as a "poetic and romantic figure, with piercing dark eyes, and wonderful hair…whose deep voice had extraordinary cadences…she might well have been the heroine of a story."[4] Later, her family nicknamed her B.G.—Beautiful Genius—and she became so famous that when she marched as a suffragette behind Emmeline Pankhurst, the police were given special orders not to arrest her.

Even though the odds were stacked against her from early childhood, Hertha rose to prominence in the male world of science. One of eight children, her father was an impoverished Polish Jewish immigrant who died when she was seven. Then called Phoebe Sarah Marks, she benefitted from a mother who recognized the advantages education could bring, and after 7 years at her aunt's school in London she became a governess and helped support her siblings. Renamed Hertha by her best friend after the earth-goddess in a poem by Algernon Swinburne, she spent her evenings studying for advanced examinations, and in 1876 went to Girton College, Cambridge, which had founded only 4 years earlier.

High-achieving women often comment on the crucial influence of networks, and Hertha benefitted from being welcomed through her aunt into the affluent community of London Jews. Her cousin was the first Jew to come top of his year in mathematics at Cambridge, and she met Francis Goldsmid, the first Jewish barrister and a sponsor of Girton College, where she went to study. Financially, Hertha was patronized by Barbara Bodichon, a campaigner for women's rights and a close friend of the novelist George Eliot.

Hertha made a great impact at Girton, where she led the Choral Society and founded the College Fire Brigade. Showing early signs of her future career in engineering, she built a sphygmomanometer (an instrument for measuring the pulse). As a woman studying mathematics, she had to be sufficiently resilient to withstand resentment not only from lecturers but also from male students. This extract from a comic verse in *Punch* is characteristic in flavor:

> The Woman of the Future! She'll be deeply read, that's certain,
> With all the education gained at Newnham or at Girton;
> She'll puzzle men in Algebra with horrible quadratics,
> Dynamics and the mysteries of higher mathematics…[5]

This mocking limerick makes some facile digs, but it also suggests that men were apprehensive about this challenge to their intellectual expertize. And well they might be—only 6 years later, Philippa Fawcett scored the highest marks in the final mathematics examinations, 13% above her nearest rival.

Hertha began studying science in London in 1884, when she took out the first of her 26 patents for a line-divider, a precision instrument she designed for architects and artists. She also attended evening classes run by William Ayrton, an electrical engineer who pioneered techniques of teaching through practical assignments. They got married the following year, and in 1891 a legacy from Barbara Bodichon enabled her to hire a housekeeper and dedicate herself to science. As Louis Pasteur famously said, "Chance favours the prepared mind" and Hertha's opportunity came when a servant accidentally lit the fire with her husband's paper on electric arcs. Taking over his research, she became the nation's expert, publishing her highly esteemed *The Electric Arc* in 1902. Continuing to develop this work, which was of great practical importance for making electric lights burn more evenly, in 1913 she invented electrodes that helped to reduce the flickering in search lights and cinema films (which continued to be known as "the flicks" for decades after the problem had been resolved).

Unanticipated circumstances also steered Hertha toward her other speciality—ripples in sand. Forced to stay at a seaside resort because of her husband's illness, she noticed the patterns on the beach, and promptly starting carrying out experiments in their lodgings before pursuing the question more systematically back in London. Whereas earlier theories had focussed on the friction of the sand on the sea floor, she showed that the problem is a more complex one of waves and turbulence within the water.

Accolades soon piled up. In 1899, Hertha became the first woman to read a paper to the Institute of Electrical Engineers (IEE), and 5 years later, she achieved a similar first at the Royal Society. Until 1958, she was the only woman to become a member of the IEE. In Britain and abroad, invitations to speak multiplied, and as she pointed out at an International Congress of Women, the new field of electrical engineering was one where women might excel: "No great physical strength is needed, but only skill in the operative, and inventiveness, and a thorough knowledge of electrical principles."[6] As if to prove the point, in 1906 she became the fifth recipient of the Royal Society's Hughes Prize for an original discovery relating to the use of energy—and to underline her exceptional talents, over a century went by before another woman was deemed worthy of this prestigious award.

Hertha Ayrton: Outsider

Although science is a communal activity, women were not treated as equal partners but were pushed toward the margins. The social innovator Marie Stopes is best known for establishing an advisory service on marital sex, but she was also Manchester University's first female lecturer (in paleo-botany). She identified isolation as a major difficulty confronting women, writing that "[w]omen high up in scientific positions, women with international reputations…are shut out from the concourse of their intellectual fellows."[7] Ayrton would surely have agreed. Although her husband was supportive, even his close friend Henry Armstrong told an American Commission on education that "History…proves the [female] sex to have been lacking in creative and imaginative power…And it must be so. Throughout the entire period of her existence woman has been man's slave."[8]

Ayrton was an extremely talented person, but it seems very likely that she would have achieved still greater success if she had been a man. Some obstacles are clear, such as the paucity of university places for women and hence the absence both of educational and of networking opportunities; her most famous scientific colleague was Marie Curie, but they became friends as scientific wives, not as scientists following the same speciality. Other hindrances may be less immediately obvious, but they also severely restricted her career possibilities. Even fully-qualified women were paid about two-thirds of a man's salary, and before her marriage, Ayrton could only find low-paid female jobs such as sewing and teaching. For 6 years, she had no time for research because she was running the marital home and looking after their daughter; furthermore, as a dutiful woman, she had little choice about caring for invalid relatives, including her sister, her mother, and later her husband.

Ayrton knew there was a substantial gap in her CV: she had no degree. Although she had passed the official examinations, Cambridge University refused to let women graduate until 1948, and she was only granted a certificate. In the years before the First World War, massive suffrage processions numbering many thousands converged on London. Most of the graduates marched in full academic dress, but to point out the University's discrimination, Cambridge delegates wore pale blue shoulder ribbons pinned to their ordinary clothes.

In principle, a scientist's appearance should be irrelevant, but it remains prominent in assessments of women. In newspaper reports of her lectures, journalists often commented on Ayrton's striking dark looks. This apparent compliment added to her exotic status as that novel specimen of humanity—a female scientist—but undermined her own attempts to emphasize her professional abilities. It also highlighted her Jewishness in an Anglican culture pervaded by anti-Semitic feelings: even Bodichon advised her that she would earn far more money if she concealed her un-English hair in a net.[9]

A scientist's political position might also seem to be a private matter, but Ayrton aroused hostility among her male colleagues by supporting the militant suffragettes in their bid to win the vote. The President of the Royal Society, William Huggins, was scathing about this campaigner who had been awarded the Hughes medal, spluttering that the news "*surprises me.* There will be great joy & rejoicing in HM's gaol, among the women in prison! I suppose Girton and Newnham will get up a night of orgies…in honour of the event!"[10] His younger wife Margaret collaborated with him in his spectroscopic research, but the numerous medals they won were awarded to him alone. It seems unsurprising that she sympathized with Ayrton, but she did also have the courage to send her a generous if private letter of support.

In my positive version of Ayrton's life, I credited her with being the first woman permitted to deliver her own lecture in 1904 at the Royal Society. That proved to be a relatively minor coup, although it was certainly a great advance since 1826, when Mary Somerville was banned from presenting her paper on magnetism, even though it was considered sufficiently important to be published in the *Philosophical Transactions*. Perhaps trying to make amends, the Society placed Somerville's marble bust in their foyer, and the real-life Ayrton entered the inner meeting room several times. Even so, when a group of distinguished scientists proposed her for fellowship in 1902, the Society managed to avoid such an innovation by falling back on a legal technicality. According to their Charter, married women were ineligible, and although the Society could in principle have got round this, the reactionary faction prevailed and Ayrton was barred.

Ayrton became still further marginalized after her husband died in 1908. The Royal Society's male President was respected as a venerable octogenarian; in contrast, as a 52-year old woman she was already regarded as becoming too elderly for scientific work. Her husband's friends blamed her for his death, feeling that if only she had "put him into carpet-slippers when he came home, fed him well and led him not to worry…he would have lived a longer and a happier life and done far more effective work."[11] Forced to research at home, and deprived of her husband's patronage, she found it hard to get her ideas considered seriously. At the beginning of World War One, she designed a wooden flapper-fan to drive poison gas out of trenches, but officials refused to take seriously her cheap and simple device that had been created in a domestic context rather than a high-tech laboratory.

Implications for Modern Science

Over a hundred years have gone by since Ayrton was refused membership of the Royal Society on the grounds that she was married. Under modern gender legislation, such overt discrimination would be impossible. But although equality of opportunity is now firmly entrenched, the problem of unequal numbers remains unresolved, especially at higher levels. Glass ceilings and leaky pipelines continue to present tough challenges for ambitious women in science.

The struggles faced by Hertha Ayrton a hundred years ago may seem to have little relevance for our modern liberated society. However, old-fashioned prejudices still prevail. Female academics repeatedly complain about being excluded from male networks, about not being invited to give keynote lectures, about being given the administrative rather than the frontline tasks. University reading-lists are dominated by male authors, and pictures of men in institutional corridors reinforce perceptions that science is a male activity. When writing about women scientists, even politically aware university students—female as well as male—regularly refer to them by their first name, oblivious to the way this both affects and reflects their own attitudes.

Whether viewed as a beautiful genius or as an outsider, Hertha Ayrton was clearly battling against difficulties imposed by society rather than by her inherent limitations. In other words, the primary problem was not that she was a woman, but that women were treated differently. In some ways, they still are. The success Ayrton did achieve was due not only to her own persistence and intellectual calibre, but also to her choice of a supportive husband. As many surveys have shown, modern working women take on far more than half the housework. Maternity leave and nursery provision make it possible for mothers to hold down a full-time job, and fathers take more care of their children that they did even 20 years ago. Even so, in many families the main responsibility for childcare lies with the mother, who is expected to cope with inconvenient events such as sickness and school holidays. Envious junior women scientists often complain that it is only possible for mothers to reach the top if their partner limits his own career—if he becomes a "house-husband."

There are still far fewer women than men at the upper levels of science, but that cannot be sidelined as a "woman's problem": these questions need to be tackled collectively by men as well as by women. Changing the position of women entails reappraising several unstated assumptions, most notably that commitment to work should take priority over family responsibilities. "The idea of 'woman and science' is completely irrelevant," Ayrton declared; "Either a woman is a good scientist, or she is not."[12] Are her words any truer now than they were then?

Notes

1. Wells, pp. 121–145 (quotation, p. 141).
2. Quoted Jones, p. 203. This excellent study of female mathematicians is my major source for considering Hertha Ayrton.
3. Quoted Mason, p. 172 (*Westminster Gazette*, 1909). Mason is my main source of biographical facts.
4. Quoted Jones, p. 12.
5. *Punch*, 10 May 1884, p. 225.
6. Quoted Mason, p. 171.
7. Jones, p. 201, quoted from *The Times,* 16 June 1914.
8. Quoted Mason, p. 176.
9. Jones, pp. 11–13.
10. Letter to Joseph Larmor, quoted Mason, p. 174.
11. Henry Armstrong's obituary of Hertha Ayrton, quoted Jones, p. 91.
12. Quoted Jones, p. 203.

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