Gender Effects in Research Funding

A review of the scientific discussion on the gender-specific aspects of the evaluation of funding proposals and the awarding of funding

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März 2012

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1 Zusammenfassung (deutsch)

1. Geschlechtsspezifische Unterschiede in der Forschungsförderung sind im Wissenschaftssystem weit verbreitet. Dabei variiert die jeweilige Intensität und Ausprägung dieser Unterschiede nach den einzelnen Ländern, Bereichen und auf den einzelnen Organisationsebenen. Ebenso gibt es Abweichungen hinsichtlich der Antragstellenden, der Geförderten, der Entscheidungsträgern und -trägerinnen in der Forschungsförderung sowie nach Förderverfahren, Förderinstrumenten und -kriterien.

2. Geschlechtsspezifische Unterschiede in der Forschungsförderung sind die Folge anhaltender geschlechtsspezifischer Unterschiede im gesamten Wissenschaftssystem, die sich in einer Vielzahl institutioneller Merkmale widerspiegeln. Zu diesen zählen insbesondere die mangelnde Präsenz von Wissenschaftlerinnen auf höheren akademischen Qualifikationsstufen, die relativ unflexible akademische Struktur mit ihren langen Arbeitszeiten sowie das Zusammenfallen der entscheidenden Etablierungsphase in der wissenschaftlichen Karriere (Ticken der „tenure clock“) und der Familiengründungsphase (Ticken der „biologischen Uhr“; Etzkowitz, Kemelgor und Uzzi, 2000), die geschlechtsspezifische Spaltung der wissenschaftlichen Aufgaben, informelle Netzwerke, die Frauen ausschließen, der traditionelle Verweis von Frauen in den „Äußeren Kreis“ der wissenschaftlichen Aktivitäten (Zuckerman, Cole und Breuer, 1991) sowie die männliche Dominanz in Peer-Review-Verfahren und anderen Bewertungsmechanismen.

3. Deutliche geschlechtsspezifische Unterschiede finden sich im Antragsverhalten (weniger Frauen als Männer beantragen Förderprojekte, die einzelnen Frauen beantragen jeweils eine geringere Zahl an Forschungsprojekten und weniger Fördermittel und erhalten im Ergebnis schlechtere Bewertungen als Männer usw.), aber nicht per se im Antragserfolg der männlichen oder weiblichen Wissenschaftler. Dabei gibt es offensichtlich einen engen Zusammenhang zwischen der akademischen Position und einer erfolgreichen Bewilligung: die niedrigeren Qualifikationsstufen, in denen sich Wissenschaftlerinnen vermehrt befinden, wirken sich dabei auf das Antragsverhalten aus. Es ist besonders wichtig, die Unterschiede im Antragsverhalten von männlichen und weiblichen Wissenschaftlern zu verstehen, weil sich die Finanzierung von Forschung international zunehmend auf Drittmittel verlagert, und der Erfolg bei Anträgen auf Drittmittel hauptsächlich von vorherigen Projektbewilligungen abhängt. Hierbei zeigt sich der so genannte „Matthäus-Effekt“ der besagt, dass renommierte Wissenschaftler bzw. Wissenschaftlerinnen größere Anerkennung erhalten („Wer hat, dem wird gegeben“; Merton, 1968). Der „Matilda-Effekt“ wirkt dagegen in die entgegengesetzte Richtung für diejenigen, die sich noch einen Namen machen müssen, und insbesondere für jene, die nicht zum Kreis der bereits Erfolgreichen gehören („ … wer aber nicht hat, dem wird auch, was er hat, genommen werden.“; Rossiter, 1993). Auch wenn andere Arten von Unterstützungen die Lage verbessern können, wie z. B. spezielle Förderprogramme für Forscherinnen, haben diese nur eine begrenzte Reichweite.

Gleichzeitig ist es wichtig, diese Unterschiede besser zu verstehen. Daher sollten mehr qualitative Daten über weibliche und männliche Antragsteller einerseits (z. B. zu deren Erfahrung mit dem Fördersystem, zu ermutigenden und hemmenden Faktoren in Antragsverfahren) und die Förderorganisationen andererseits (deren Förderkultur, Richtlinien und Verfahren, Veränderungen im Laufe der Zeit, Erfahrung des Programmemverantwortlichen in der Verwaltung des Programmems, Bewusstsein des Programmemverantwortlichen für Chancengleichheit usw.) erhoben werden.

4. Akademisches Mentoring für männliche und weibliche Wissenschaftler stellt einen Schlüsselfaktor zur erfolgreichen Beantragung von Fördermitteln dar, besonders für Akademikerinnen zu Beginn ihrer Laufbahn. Mentoring bewirkt außerdem mehr Zufriedenheit mit der Zeiteinteilung am Arbeitsplatz, eine (empfunden) höhere akademischen „Selbstwirksamkeit“ (die Erwartung, aufgrund eigener Kompetenzen gewünschte Handlungen erfolgreich selbst ausführen zu können), bildet weiter und erhöht die Publikationstätigkeit. Auch auf das Engagement von Wissenschaftlerinnen und Wissenschaftlerinnen in verschiedenen akademischen Aktivitäten hat Mentoring einen positiven Einfluss. Dies führt insgesamt zu einer positiveren Arbeitserfahrung und -zufriedenheit, führt zusätzliche Beschäftigungsalternative vor Augen, aber erhöht auch die Erwartungen an die eigene Karrierelaufbahn. Ebenso werden die eigenen Rollenkonflikte und die eigene Rollenambiguität vermehrt wahrgenommen. Mithilfe qualitativer und quantitativer Forschungsmethoden ist noch genauer zu untersuchen, aus welchem Grund Mentoring so eine große Bedeutung für Förderprozesse hat und worin die Ursachen dafür liegen, dass die Verfügbarkeit von Mentoring für Frauen im Gegensatz zu Männern geringer ist. Dazu gehören auch Tiefeninterviews mit Mentoren und Mentees sowie Analysen ihrer Erfahrungen.

5. Unterschiede, die in persönlichen und sozialen Verpflichtungen von Wissenschaftlerinnen und Wissenschaftlern (Familienstand, Kinder, häusliche Pflege usw.) sowie in anderen individuellen Faktoren (Einstellungen, Motivation und Selbstvertrauen der Frauen, die Angst, als zu dominant und konfrontativ wahrgenommen zu werden, usw.) liegen, können das Antragsverhalten und den Antragserfolg entscheidend beeinflussen, haben aber geringere Auswirkungen auf die akademische Produktivität. Unterstützungsstrukturen im sozialen Umfeld sind notwendig, um die negativen Auswirkungen dieser „Rollenüberlastung” möglichst gering zu halten. Es ist jedoch noch nicht ausreichend erforscht, warum diese Unterstützungsstrukturen oder sozialpolitische Maßnahmen einigen Frauen zum Erfolg verholfen haben und anderen nicht. Um über zukünftige Maßnahmen entscheiden zu können, bedarf es weiterer Untersuchungen.

6. Quantitative Standard-Methoden wie das statistische Matching („Bildung statistischer Zwillinge“) können die Benachteiligung von Frauen verdecken, da männliche Antragsteller normalerweise zahlreicher sind und mit größerer Wahrscheinlichkeit höhere Positionen innehaben, aus denen heraus sie Projekte beantragen und für die sie mehr Projektmittel erhalten. Doch gibt es nicht nur weniger Antragstellerinnen in höheren Qualifikationsstufen, sondern diese stellen auch seltener Anträge auf Fördermittel. Eine weitere Methode, um den Erfolg

von Männern und Frauen in der Forschungsförderung zu messen, ist die Bewilligungsquote, die das Verhältnis der Bewilligungssumme zur Antragssumme berechnet. Bei diesem Vergleich ergeben sich für Frauen signifikant niedrigere Ergebnisse. Dieses Ungleichgewicht zeigt sich deutlicher in den höheren Qualifikationsstufen der akademischen Laufbahn. Ein Vergleich zwischen Antragstellern und Antragstellerinnen in Einstiegspositionen und denen, die bereits auf einer höheren akademischen Ebene tätig sind, könnte dazu beitragen, die Unterschiede und gegebenenfalls die Wirkungen von Maßnahmen zu beurteilen.

7. Frauen sind in Positionen, in denen wichtige Entscheidungen getroffen werden (gatekeeping positions), weiterhin unterrepräsentiert. Dies liegt vor allem an ihrer mangelnden Präsenz in höheren akademischen Qualifikationsstufen und daran, dass das Peer-Review-System bekanntermaßen etablierte Personen aus Wissenschaft und wissenschaftspolitischen Organisationen bevorzugt, wo Frauen systematisch unterrepräsentiert sind. Ein besseres Verständnis der Auswahl- und Beförderungsmechanismen von Frauen in solchen Entscheidungspositionen ist vonnöten.

8. Die Forschungsproduktivität von weiblichen Wissenschaftlern liegt insbesondere in den ersten zehn Jahren ihrer wissenschaftlichen Tätigkeit hinter der ihrer männlichen Kollegen, auch wenn die geschlechtsspezifischen Unterschiede im Laufe der Zeit langsam abnehmen. Es wurde bereits eine Vielzahl von Gründen als erklärende Faktoren genannt, aber eine zufriedenstellende und belastbare Erklärung der Geschlechtsunterschiede in der wissenschaftlichen Produktivität wurde bislang noch nicht gefunden (Long, 1992: 6).

9. Untersuchungen zu einem geschlechtsspezifischen Bias im Peer-Review von wissenschaftlichen Publikationen weiblicher und männlicher Forschender kommen je nach Fachzeitschrift und Disziplin zu unterschiedlichen Ergebnissen. Weitere Daten sind nötig, um das Ausmaß und die Determinanten des Verfahrens benennen zu können.

10. Insgesamt gibt es derzeit wenig „fundiertes Wissen“ über Geschlechterverzerrungen in der Forschungsförderung. Die Ergebnisse bisheriger Studien hängen stark von der jeweiligen Förderorganisation, der Forschungsdisziplin, der verwendeten methodischen Vorgehensweise usw. ab und waren häufig einmalige Erhebungen, d.h. die Ergebnisse wurden selten in Folgestudien aufgegriffen, die Einblicke in Veränderungen im Laufe der Zeit ermöglicht hätten. Bis auf wenige Ausnahmen (z. B. die Studie von Wennerås und Wold in Schweden, die einige Jahre später wiederholt wurde und herausfand, dass Nepotismus und Geschlechterunterschiede im Wissenschaftssystem weiterhin bestehen) können die bisher durchgeführten Studien als singuläre Anhaltspunkte betrachtet werden, auch wenn Übereinstimmungen erkennbar sind. Dies betrifft z. B. die Antragstellung. In verschiedenen Studien waren zwar durchaus Geschlechtsunterschiede in den einzelnen Stufen des Entscheidungsprozesses erkennbar, aber nicht im Bewilligungserfolg von Projekten.

11. Geschlechtsspezifische Unterschiede in der Forschungsförderung sind hauptsächlich in der Kluft zwischen den Geschlechtern im Wissenschaftssystem und in den institutionellen Hindernissen für Frauen, die im akademischen „Establishment“ verankert sind, begründet. Die-

se Hindernisse ähneln sich in den einzelnen Ländern, Regionen oder Forschungssystemen. Wenn nach Unterschieden in der Forschungsförderung in den einzelnen Ländern/Regionen/Forschungssystemen gesucht werden soll, so sollte der Blick auf die Unterschiede in der Funktions- und Arbeitsweise des gesamten akademischen Bereichs in den jeweiligen Ländern/Regionen/Forschungssystemen gerichtet werden. Hierzu liegt umfangreiche Literatur vor, die jedoch außerhalb des Fokus dieses Berichts liegt. Des Weiteren ist die Mehrzahl der in dieser Studie besprochenen Artikel neueren Erscheinungsdatums, also maximal sechs bis acht Jahre alt. Das Thema der geschlechtsspezifischen Ungleichheiten in der Forschungsförderung ist noch ein sehr neues Forschungsfeld und es liegt damit keine ausreichende Evidenz bzw. es liegen nicht genügend Studien vor, um aussagekräftige Schlüsse zu Unterschieden speziell in der Forschungsförderung zwischen Ländern, Regionen oder Forschungssystemen ziehen zu können. Zusammenfassend konzentrieren sich die vorliegenden Untersuchungen also sehr spezifisch auf die Mikroebene der Institution/Förderorganisation und lassen deshalb keine aussagekräftigen Schlüsse auf die Makroebene der Länder/Regionen/Forschungssysteme zu. Da sich geschlechtsspezifische Auswirkungen von Peer-Review-Verfahren von nationalen und internationalen Förderorganisationen außerdem in den Forschungsdisziplinen und Analyseebenen höchst unterschiedlich gestalten, könnten Tiefeninterviews mit Antragstellenden und Gutachtenden über deren Erfahrung hilfreich sein, um die Funktionsweise des Peer-Review-Verfahrens zu erforschen.

12. Welche Maßnahmen und politischen Instrumente empfohlen werden können, um einen Wandel herbeizuführen, hängt hauptsächlich von der Ebene ab, auf der die jeweiligen Herausforderungen liegen: Dies können z. B. die Antragstellenden oder die institutionelle Hürden oder Richtlinien sein, die zu einer geringeren Anzahl von Frauen unter Antragstellenden oder in Entscheidungpositionen führen. Ebenso lässt sich der Blick auf das geringe oder nicht vorhandene Gender-Bewusstsein oder die Informationen, die im Antragsbearbeitungsprozess in Hinsicht auf Geschlechtsunterschiede gesammelt werden, richten. In der vorliegenden Studie werden für jeden dieser Fälle verschiedene Strategien und korrigierende Maßnahmen empfohlen.

2 Executive Summary

1. Gender disparities in research funding are a widespread phenomenon in the scientific community, with various intensity across countries, disciplines and organisational levels, applicants, recipients and gatekeepers of research funding, in funding processes, instruments and criteria.

2. Gender disparities in research funding are a consequence of the long-standing gender divide in science that is apparent in a multitude of institutional features. Among them, particularly relevant are the attrition of women scientists at the higher academic levels, the relatively inflexible academic format with its “long hours culture” and the “contradiction between the tenure clock and the biological clock” (Etzkowitz, Kemelgor and Uzzi, 2000), the gendered segregation of scientific work, informal networks that exclude women and women’s traditional relegation to the “outer circle” of scientific activity (Zuckerman, Cole and Breuer, 1991), as well as the male dominance of peer-review and other evaluation mechanisms.

3. Significant gender differences have been reported in grant application behaviour (fewer women than men applying for grants, applying for smaller numbers of grants and requesting smaller amounts, obtaining smaller scores than men etc.), but not in the male or female faculty’s success in acquiring grant funding, per se. Academic position and funding success appear to be strongly correlated: women’s lower level of appointments carries over into funding application behaviour. Understanding the differences in male vs. female scientists’ funding behaviour is all the more important as research funding increasingly shifts to the grant mode, internationally, and funding success depends to a large extent on previous awards and grants. This is a manifestation of the ‘Matthew effect’, whereby greater recognition is given to established scientists (Merton, 1968). Conversely, a Matilda effect works in the opposite direction for those yet to make their mark and especially for those who are distant from the already successful (Rossiter, 1993). While other modes of resource allocation, such as funding that is made available only to women researchers, may improve the situation, they remain very limited. At the same time, in order to better understand these differences, more qualitative data needs to be collected regarding, on the one hand, the female and male applicants (e.g. experience with the funding system, encouraging and inhibiting factors in the application process) and on the other, the funding agencies (funding culture, policies and practices, change over time, programme officers’ experience in programme management, programme officers’ gender awareness, etc.).

4. Academic mentorship for male and female scientists is a key factor for success in acquiring research grants, especially for women junior faculty members. Mentorship is also associated with greater satisfaction with time allocation at work, higher academic self-efficacy scores, enhanced residency training and publication productivity, higher engagement in a variety of academically-oriented activities, more positive job experience and the perception of more employment alternatives, organisational commitment, job satisfaction, career progress ex-

pectations, perceived employment alternatives, role conflict and role ambiguity. What precisely makes mentorship so important in the funding process and the causes of lower availability of mentorship for women than for men need to be better investigated through qualitative and qualitative research methods, including in-depth interviews with both mentors and mentees, and analyses of their experiences.

5. Differences in personal and social responsibilities of male and female academics (marital status, children, domestic and elderly care, etc.) and in other individual factors (women's attitudes, motivation, self-confidence, fear of being perceived as highly assertive and confrontational, etc.) can significantly influence grant application behaviour and success, but have a lesser effect on their academic productivity. Social support structures are essential in minimising the negative effect of this “role overload”, but the way they helped some women to succeed, while others have failed, is less explored. More information is needed on the role of social support structures and impact of social policy measures on those women who have succeeded despite obstacles, as well as those who have not, in order to determine what additional steps might be undertaken.

6. Standard measurement methodology of matched comparisons can obscure women’s disadvantage, as male applicants are usually more numerous than women and more likely to hold senior positions from which they can apply for and receive larger grants. Women applicants in senior positions are not only fewer, but are also less likely to apply for funding. Another procedure of comparing men and women’s success in research funding − the money success rate − calculated as the amount of funding allocated/amount of funding requested, is significantly lower for women. These disparities are more visible at the upper levels of the academic career. Comparison between male and female applicant numbers at entry level and at higher academic level could help understand differences and effect, if any, of interventions.

7. Women continue to be under-represented in gate-keeping positions, largely due to their attrition in senior positions in academia and to the recognised bias of the peer-review cadre towards the elite of science and science policy organisations in which women are systematically under-represented. Better understanding of the mechanisms of selection and promotion of women to such gate-keeping positions is needed.

8. Women scientists’ research productivity, especially during the first decade of scientific activity, continues to be inferior to that of men, although gender differences have slightly declined over time. A variety of reasons have been suggested as explanatory factors, but "satisfactory and robust explanations of sex differences in scientific productivity remain elusive" (Long, 1992: 6).

9. The evidence on the gender bias of the peer-review process of women and men scientists’ publications is mixed across journals and disciplines. More data is needed in order to better understand the extent and determinants of the process.

10. Overall, ‘consolidated knowledge‘ about the gender bias in research funding is difficult to obtain at this stage, as the evaluations undertaken so far are highly dependent on agency, research discipline, methodological approach adopted, etc. and are one-off exercises, rarely followed by follow-up studies to assess change of patterns over time. With few exceptions (e.g. the Wennerås and Wold study in Sweden, which was replicated a few years later and found that nepotism and gender differences still existed in the scientific system), the evaluations performed so far could be considered as singular evidence, although some convergence can be identified, e.g. in the application behaviour, where gender differences were found in the stages of the process, but not in the success in acquiring funding.

11. Gender disparities in research funding are essentially rooted in the gender divide in academic science and in the institutional obstacles to women that are embedded in the academic establishment. These obstacles are pretty much the same across countries, regions or research systems. If one is looking for differences between countries/regions/research systems in research funding, then the main focus of attention should be on differences between countries/regions/research systems in the structure and functioning of the scientific establishment. There is a wide literature on this latter aspect, which is outside the focus of this report. Second, most of the articles reviewed in this report are very new − max. 6-8 years old. The topic of gender disparities in research funding is very new and there is not enough evidence to build pertinent conclusions about differences across countries, regions or research systems in research funding as a stand-alone body of evidence. In conclusion, the available evidence is highly specific to the micro-level of the institution/funding agency and does not allow drawing pertinent conclusions at the macro level of country/region/research systems. Also, as gender-specific effects of peer-review procedures of national and international funding agencies are highly variable across fields and levels of analysis, in-depth interviews with applicants and peer-reviewers on their experience could be useful to clarify the inner workings of the peer-review process.

12. Measures and policy recommendations to encourage change depend essentially on the level at which specific challenges may lie, e.g. the applicant, the institutional obstacles or policies determining lower numbers of women among applicants or gate-keepers, the poor/lack of a gender awareness culture, the information collected by the grant application and award data systems with respect to gender differences. Several policies and corrective measures are re-commended in each case.

3 Introduction

The question of gender disparities in research funding, with female scientists less funded than their male counterparts, originally emerged as part of the so-called “productivity puzzle” (Cole and Zuckerman, 1984), referring to persistent differences in research productivity between academic men and women, reported in American and European studies since the 1970s (e.g. Cole and Cole, 1973; Blackburn and Fulton, 1975; Cole and Cole, 1979, Astin and Bayer, 1979; Cole and Zuckerman, 1987; Zuckerman, 1991; Bailey, 1992). Gender bias in research funding remained a matter of dispute until Wennerås and Wold (1997) conclusively demonstrated the existence of discriminatory actions in Sweden and placed the issue at the forefront of the gender, science policy and research agenda internationally. The study galvanized many other European and US funding institutions into action, and in the following years was followed by several assessments of possible gender bias in funding mechanisms.

The phenomenon appears to be widespread in the scientific community, albeit with varying intensity across countries, disciplines and organisational levels. For example, in the European Union member states and associated countries, gender effects in research funding have been identified among applicants, recipients and gatekeepers of research funding, in funding processes, instruments and criteria, and in the role of key funding organisations in promoting gender equality in research (European Commission, 2009). In most disciplines, decision-making and other gate-keeping activities in research funding, including peer-review, continue to be male dominated, in some cases overwhelmingly so, and the recruitment procedures, in particular for peer-reviewers, whose choice may be crucial, are often not clear (ibid.). Moreover, gender-based double standards in assessing scientific competence and excellence further widen the funding gap (European Commission, 2004). The phenomenon has also been reported in the top US research universities, where, although male and female faculty in science, engineering and mathematics have similar access to many kinds of institutional resources, there were some resources for which male faculty seemed to have an advantage (e.g. research equipment, clerical support, lab space) (National Academies of Science, 2010).

Gender disparities in research funding are essentially a manifestation of the long-standing gender divide in science, with its multitude of aspects, from the demographics, culture and dynamics of the academic community to its reward and incentive system and the persistence of a “male model” of scientific career as the norm to which women must conform (Etzkowitz, Kemelgor and Uzzi, 2000). Nevertheless, the specific mechanisms that may, knowingly or unknowingly, generate a gender bias in the functioning of academic funding mechanisms are less known. In order to systematically explore these specific mechanisms, the report is structured as follows:

Section 1 provides an analysis of the most salient features of the gender divide in science, as the origin of gender differences in funding mechanisms. In this section, the focus is placed on key institutional features of the gender divide in science, such as the attrition of women scientists at the higher academic levels, the relatively inflexible academic format with its "long hours culture" and the "contradiction between the tenure clock and the biological clock" (Etzkowitz et al. 2000), women's traditional relegation to the "outer circle" of scientific activity (Zuckerman, Cole and Breuer, 1991), the gendered segregation of scientific work, and the male dominance of peer-review and other evaluation mechanisms.

Section 2 examines gender-specific differences in application behaviour, such as different patterns of application behaviour for male and female academics (without a significant gender difference in acquiring research funding), the importance of academic mentorship and of individual factors in receiving research funding, and the way the measurement of research funding performance can obscure women's disadvantage.

Section 3 focuses on gender-specific effects of peer-review procedures, such as the high variability of gender-specific effects across fields and levels of analysis, identified in peer-review procedures of national and international funding agencies, and women's persistent underrepresentation in gate-keeping positions, largely as a consequence of their attrition in senior positions in academia.

Section 4 examines gender-specific evaluation of scientific merit (e.g. publications), including women scientists' lower research productivity compared to men's, and the mixed evidence on the gender bias of the peer-review process of women and men scientists' publications.

Section 5 concludes the report with a synthesis of findings and several recommendations for counteracting gender disparities in research funding discussed previously.

4 Gender disparities in research funding and the gender divide in science

Gender disparities in research funding and the gender divide in science are closely related in a bi-directional flow of causality.

Gender disparities in research funding are tightly knit together with a multitude of long-standing and persistent features specific to the gender divide in science that often makes it hard to establish which of these elements is a cause and which is an effect. The consequences of the gender divide in science on the male vs. female scientists' chances to obtain research funding are all the more important as research funding increasingly shifts to the grant-project proposal mode, internationally, and funding success depends to a large extent on previous awards and grants − a manifestation of the 'Matthew effect', whereby greater recognition is given to established scientists whose contributions are more readily accepted (Merton, 1968). Conversely, a Matilda effect works in the opposite direction for those yet to make their mark and especially for those who are distant from the already successful (Rossiter, 1993). In this section, we place the focus on several institutional factors characterising the gender divide. Individual factors, no less important for the gender divide, will be discussed in the next section, taking into account their high relevance for the grant application behaviour.

Institutional factors include:

- The **attrition of women scientists at the higher academic levels**: disproportionate numbers of women remain in low-level positions in academia, disconfirming the "pump-priming" hypothesis that upward mobility in professional hierarchies would occur naturally once entry was assured. Reality contradicted expectation: the 'pipeline' model of linear progression through a series of staged roles turned into a 'leaky pipeline', where women in science, engineering and technology (SET) careers are lost at every educational transition stage. The transition from postdoctoral fellow to faculty emerges as the first and most critical step at which a worrying number of female postdoctoral fellows are lost to academic research (Martinez et al., 2007). This is a consequence of a combination of external, family-related challenges and internal, self-confidence challenges that negatively influence the opportunities and choices of women and make this transition a much more critical period in the career of a female scientist than that of a male scientist. Those who make it through this bottleneck continue to face new challenges when trying to achieve scientific recognition. Beyond the postdoctoral level, women scientists have slower rates of promotion and less recognition through awards and hold fewer departmental chairs relative to the eligible pool (National Academy of Sciences, 2007; Committee on Gender Differences in the Careers of Science, Engineering, and Mathematics Faculty and Committee on Women in Science, Engineering, and Medicine; National Research Council, 2009).

- This loss has been a **long-standing matter of concern** in science and technology (e.g. Pell, 1996; Wickware, 1997). Recent evidence suggests that up to 52% of highly quali-

fied women in science, engineering and technology (SET) careers may quit their jobs at a critical “fight-or-flight” moment in their career, producing massive labour shortages in SET fields (Hewlett et al., 2008). Harvard University’s appointment of a female president in 2007 was a watershed moment for women in academia, but also a notable exception in a university where women accounted for only 20% of full professors, al-though they made up 56% of the undergraduate population and were predicted to earn more than 60% of the university’s master’s degrees and nearly half of doctoral degrees by 2010 (West and Curtis, 2006).

- **Computer science** is one discipline where this conundrum is especially evident. For example, at the Massachusetts Institute of Technology, women made up 51% of science undergraduates and 35% of its engineering undergraduates in 2007 (National Academies of Sciences, 2007). This is a vast improvement over just a few decades ago, yet few women hold senior professorships in most computer science departments and fewer receive venture capital investments for software firms.

- Women’s concentration in lower grade employment status and in fixed-term positions makes them **less likely than men to be eligible to apply for research grants** as many of the grant schemes provided by the main funding bodies are not open to academic staff in these groups (Blake and La Valle, 2000). Also, women get less grant money and years awarded than men because men occupy a greater proportion of high positions from which it is possible to apply for and receive larger grants (Waisbren et al., 2008). A similar observation has been made also by Gordon et al. (2009), who note that male faculty’s greater likelihood to hold an advanced research degree allows them to request more money, obtain more favourable application scores and receive higher awards than women

- **A relatively inflexible academic format**, with a “contradiction between the tenure clock and the biological clock” (Etzkowitz et al. 2000), i.e. frontloading of the academic career coinciding with child-bearing years, makes it difficult for women to compete. Also specific for the academic life is a “long hours” culture that makes the work-life balance difficult, as well as an implicit “rule of exogamy” at key transitions points in the academic career, especially in the US, where it is expected that for the highest academic careers one has to move from one academic site to another to secure maximum potential advancement. This choice is socially less available to women than to men (Etzkowitz et al., 1994).

- **A gendered “separation of labour” in science,** with women better represented in the biological sciences and medicine, and men in the physical sciences and enginee-ring. Similar phenomena may be observed at more fine-grained levels within particular medical, nursing and engineering subfields. These bifurcations have traditionally been associated with significant status differentiation between male and female profession-nals (Etzkowitz, 1971). One explanation for this is the phenomenon of “territorial sex segregation” and “ghettoization” (Rossiter, 1982/1995). As the supply of qualified women rose and new opportunities in scientific work emerged from the development of ‘big science’ and the need for large staffs of assistants in research centres, women were utilized as research associates or sidelined into fields that were low in status and lacking in resources.

- **Women's traditional relegation to the "outer circle" of scientific activity** (Zuckerman et al., 1991) and disadvantage in informal networks of communication among academic colleagues through the operation of a "stag effect" in which men exclude women from informal communication processes along which emerging scientific knowledge is disseminated (Bernard, 1964). An indirect manifestation of this separation is also the lower availability/lack of mentoring for women than for men (e.g. Didion, 2009; Bonetta, 2010), resulting in lower grant funding success for women.

- **Male-dominated academic peer-review and evaluation procedures**. However, even when women are present, they often evaluate women applicants more severely than men, perhaps to insure against being charged with favouritism, often associated with male members favouring male candidates and perhaps expecting women to favour women (Broder, 1993). Long's National Research Council Report (2001) also highlights the expectation for women to meet higher standards for promotion at research universities, which suggests that although overt discrimination against women in science has effectively ended, covert discrimination continues unabated.

5 Gender-specific differences in application behaviour

1. Significant gender differences exist in grant application behaviour and in the amount of funds received, but not in the male or female faculty success in acquiring grant funding, per se.

a. Methodology and description of results

Gender differences in grant application behaviour, but no significant differences in success in acquiring research grants has emerged as a common finding of several studies.

Although it is widely believed that in some countries or disciplines, men have significantly higher 'success rates' than women in receiving grant funding (where 'success rate' is defined as the ratio of the number of proposals funded to the number submitted and commonly expressed as a percentage), a recent assessment of 'success rate' of male and female researchers in the main research grant-funding programmes of 27 of the 33 EU member states and associated countries examined in 2007 found no systematic patterns and also no clear relation between the proportion of women in a field and their chances of success in obtaining funding (European Commission, 2009).

A reference study of male and female scientists' behaviour in applying for grants provided by all Research Councils and the Wellcome Trust, except for the ESRC (Blake and La Valle, 2000) surveyed 44 academic institutions in the UK. A total of 3090 academic staff drawn from 44 Higher Education institutions in Great Britain took part in the survey, which achieved a 40% response rate. The study found that female researchers were as successful in gaining funding as their male colleagues, but significant differences were identified in females vs. males' application behaviour. For example, fewer women than men applied for grants, they applied for smaller numbers of grants and requested smaller amounts (regardless of the grant type). The main factors influencing the application behaviour included: seniority, employment status, tenure, type of institution, professional profile, institutional support, career breaks and family circumstances. Whilst many of these factors affected both men and women, some disproportionately stopped women from making applications. For example, some eligibility criteria designed by research funders were found to produce a gender bias at the application stage, because more women than men were employed on fixed term contracts and were at lower academic grades.

The investigation of several large Swedish scientific funding programmes (Nervik, 2006, cited in Melin, 2007) revealed women's lower propensity to apply compared to men. A likely cause for the lower number of applications was identified in the internal selection process in place at the respective universities, which was inhibiting women's applications. Furthermore, lower success of women in getting grants and a tendency to a negative selection of women in each single step of the selection process were reported, even if the selection process was comprehensive and transparent. The strongest women under-representation was found in Life Sciences and Medi-

cine.

A study of the outcomes of grant applications submitted by women vs. men to three US federal agencies: the National Institutes of Health (NIH), NSF and the Department of Agriculture (USDA) investigated the probability of getting funded, the funding requested, the size of the award, and the probability of applying again during the fiscal years 2001 through 2003 (Hosek et al., 2005). The study found gender differences in federal grant funding outcomes in two areas:

- In women's applications as principal investigators to NIH. Women received on average only 63% of the funding that male applicants received, while at NSF and USDA, there were no differences between men and women in the amount of funding requested or awarded;

- In the fraction of first year applicants who submitted another application in the following two years. At NSF and NIH, women who applied in 2001 were less likely to apply again. The difference was much larger at NIH (more than 20%) than at NSF (5%), and it applied for both successful and unsuccessful applicants in the first year. This was considered as a reflection of underlying gender differences in application propensity.

Women accounted for 21-28% of applicants to NSF, NIH, and USDA in recent years, which was similar to women's representation in the population of doctoral recipients working in science and engineering. The study also showed that female researchers followed somewhat different career paths than male researchers, and were less likely to be employed in the major research universities, where most research grants are awarded to. In addition, the study revealed many limitations in the information collected by federal grant application and award data systems, which prompted a number of recommendations on how the federal agencies could improve their tracking of gender differences.

The methodological approach of the study included in addition to the three federal agencies (NIH, NSF and USDA) an analysis of the 1999 National Survey of Postsecondary Faculty and the 2001 Survey of Doctorate Recipients, which comprise more-limited information on grant funding provided by all federal agencies. Four variables were considered:

1. Total amount of funding requested from an agency in a year;

2. Total amount awarded by an agency in a year;

3. Whether an award is given − i.e., the applicant's proposal(s) is accepted; and

4. How much funding is awarded, given that the applicant gets an award.

For each of these four variables, simple averages for women vs. men have been provided for each agency over the three years of concern (2001-2003), then adjusted gender differences were calculated based on regressions that controlled for the effects of other factors, such as age or experience, type of research institution the applicant was from, and type of grant pro-

gramme. Then the data for differential gender effects within each agency was explored, by personal characteristics of the researcher (e.g., experience or age) and across different grant programmes or types.

In a study of the Committee on Women in Science, Engineering, and Medicine (CWSEM) of the US National Research Council (NRC) (Didion, 2009), no significant gender differences were found in the probability that male or female faculty would have grant funding (a Principal Investigator/PI or Co-PI on a grant proposal) with the exception of biology, where male faculty had significantly more research funding than female faculty. In the other disciplines, differences were not significant.

Similarly, no differences in acquiring grants have been found for full-time male and female faculty at eight Harvard Medical School-affiliated institutions, who were equally successful over the period 2001-2003, although submission rates by women were significantly lower at the lowest faculty rank (Waisbren et al., 2008). These lower submission rates were largely explained by gender disparities in academic rank, the key factor discussed in Section 1.

Although there was no difference in the proportion of money awarded to money requested, there were significant gender differences in the application behavior: mean number of submissions per applicant (women 2.3, men 2.7), success rate (women 41%, men 45%), number of years requested (women 3.1, men 3.4), median annual amount requested (women $115,325, men $150,000), mean number of grant years awarded (women 2.9, men 3.2), and median annual amount awarded (women $98,094, men $125,000). Women were awarded significantly less money than men at the ranks of instructor and associate professor. More men than women applied to the National Institutes of Health, which awarded higher amounts than other funding sources. The methodological approach of the study was based on data from the participating institutions on all research grant applications submitted by full-time faculty from 2001 through 2003. Data were analyzed by gender and faculty rank of applicant, source of support (federal or non-federal), funding outcome, amount of funding requested, and amount of funding awarded. Data on 6319 grant applications submitted by 2480 faculty applicants were analyzed, where women represented 29% of investigators and submitted 26% of all grant requests.

Yet another study reporting similar results to the above is Gordon et al. (2009), which found no significant differences in the success rates of medical school faculty (male and female applicants) at the resident level, among paediatric residents, although men were found to request more money and obtain more favourable application scores than women. Among funded applicants, men received higher awards than women, although the percentage of requests funded was the same. These differences were explained in part by the correlation of male gender with holding an advanced research degree, as among all applicants, men were more likely than women to hold an advanced research degree. The study is based on a retrospective review of all applications to an internal, mentored research grant fund at a large academic paediatric residency programme from 2003 to 2008 in the United States.

Preush (2004) identified in a study on NIH grants a similar success rate of applications from

women to that of men over the period 1980-2003, although a few percent below in most years. Moreover, the average award to women was been found to be greater than the average award to men since 2000, and increases in Career Awards to women have been approaching 35% of the total.

Ley and Hamilton (2008) suggest that men and women's near-equal NIH funding success at all stages of their careers is more a consequence of women's disproportionate career attrition at the higher academic levels, rather than a consequence of negative selection from the funding agency's decisions, once again reaffirming the fundamental salience of academic rank to funding success. Nevertheless, many qualified women scientists stopped applying for NIH grants in the late postdoctoral and early faculty years, which points to the need to develop more effective strategies to retain women at the critical juncture between postdoctoral training and independent careers. The study was based on NIH data and aimed to define the gender of each grant applicant and to determine the funding success rates for specific grant types that reflect different stages in the careers of biomedical scientists. The data was evaluated in the context of the degrees held by the applicants, as people with different training backgrounds applied for different types of grants.

In addition to gender differences in application behaviour, Ackers (2001) also highlights further complications arising if the research grant involves mobility of the researcher. Her study of the European Commission's mobility fellowships in 1998-99 (then called the 'TMR' programme under the Fourth Framework Programme), based on interviews with 159 Marie Curie fellows and key informants in participating countries, found that women were in a minority in terms of applications. Women comprised 39% of applicants for PhD fellowships and 33% for postdoctoral fellowships. Men were slightly more successful than women in both grant forms. Reasons for the lower participation of women in applying for the TMR fellowships included:

- the impact of previous mobility (i.e. previous stay abroad on some form of undergra-duate mobility programme, for example Erasmus) on the propensity to move (the majority of fellows had lived abroad prior to their TMR application);
- the impact of mobility on partnering and parenting, on own science careers and the specific challenges facing dual science career couples,
- the concern that repeated moves may affect the employment conditions associated with the formative stages of research careers,
- relatively long period of pre-qualification prior to the achievement of employment security,
- the problem of fixed-term contracts and of inflexible (and typically very long) working hours,
- the impact of occupational cultures and 'commitment' on confidence levels and grant application behavior.

b. Discussion of research gaps

Studies of funding application behaviour highlight significant gender differences in the application process itself (e.g. propensity to apply for grant funding, number of grants applied for, amount of funding requested, etc.) but not in the success of acquiring grant funding. Overall, there is a strong relationship between academic position and funding success, both in the propensity to apply and the amount of funds received. Women's lower level of appointments, the key variable explaining gender difference in research funding achievement, carries over into funding application behaviour.

In order to better understand these gender differences in application behaviour, greater attention should be paid to the lack of data regarding the parties involved, or in other words, both the supply side and the demand side of the process:

- On the one hand, the female and male applicants: more qualitative data (e.g. interviews, surveys) on their experience with the funding system is necessary for understanding the key encouraging and inhibiting factors in the application process (e.g. individual factors, factors pertaining to the academic system structure and promotion policies, internal selection factors, external policy factors, better knowledge of the grants and evaluation procedures, etc.), the impact of occupational cultures and 'commitment' on confidence levels and grant application behavior.

- On the other hand, the funding agencies: there is a relative lack of studies of granting agencies' policies and practices, and most of the existing studies only describe the results of one-off evaluations, rather than successive evaluations that would allow to assess a change over time in these policies and practices. Also, the evaluation procedures vary significantly from one agency to another. In addition, relatively little is known about the respective programme officers' experience, as 'gate-keepers', in managing the programmes of concern, or the gender dimension among programme officers.

2. Availability of mentorship for male and female scientists is a key factor for success in acquiring research grants.

a. Methodology and description of results

The importance of mentorship for research funding success is another significant common conclusion of several studies focusing on research funding prerequisites. For example, Bonetta (2010) reports the findings of a survey of tenure-track and tenured faculty in six academic disciplines (biology, chemistry, mathematics, civil engineering, electrical engineering, and physics) at 89 US institutions in 2004 and 2005, which revealed that female assistant professors who had a mentor had a 93% probability of receiving grants, while those who did not have a mentor had only a 68% probability to receive grants. A similar result is reported by Didion (2009), which points to a particularly striking manifestation of this effect in chemistry, where female assistant professors with mentors had a 95% probability of having grant funding vs. 77% for those without

mentors. The pattern identified for female assistant professors was in stark contrast with that for male assistant professors: those with no mentor had an 86% probability of having grant funding versus 83% for those with mentors.

Having a mentor was also associated with other factors that increase the chances of getting research funding, such as greater satisfaction with time allocation at work and with higher academic self-efficacy scores (i.e. one's perceived ability to perform tasks within a specific domain; Feldmann et al. 2010), a good understanding of gender differences in social behaviour and culture of academic systems (King and Cubic, 2005), provision of career development support, which appears to be different for male mentees than for female mentees. For example, Ortiz-Walters et al. (2010) report that among MBA students at large US universities on the East Coast, male mentees, who strongly identify themselves with their career roles, were more satisfied with mentors who provided career development support, while female mentees, who measured career success using socio-emotional-based criteria, reported being more satisfied with mentors who provide psychosocial support. Similarly, O'Brien et al. (2010) found that male mentees received less psychosocial support than female mentees.

Starting from the premise that peer-based mentorship represents a vehicle to foster knowledge translation (KT) capacity, Canadian researchers sought to identify mentoring models that could be used to build KT capacity, consult with putative mentee stakeholders to understand their KT mentorship needs and preferences, and generate recommendations for the content and format of KT mentorship strategies or programmes. A conceptual framework was derived based on mentoring goals, processes and outcomes identified in the management and social sciences literature, and research on barriers and facilitators of academic mentorship (Gagliardi et al., 2009).This points to the more general issue of measuring the success/effectiveness of measures to promote women, which, in general, is a matter of internal evaluation of the respective measures in relation to specific targets or objectives set by the institutions concerned.

b. Discussion of research gaps

Availability of mentorship is reported to be an important condition for success in acquiring grant funding, especially for women junior faculty members. However, what precisely makes mentorship so important in the funding process is less explored. Also, the factors that generate the lower availability of mentorship for women than for men need to be better investigated through both qualitative and qualitative research methods, including in-depth interviews with mentors and mentees, and analysis of their experience in general, and with respect to funding in particular.

3. Personal and social responsibilities and other individual factors can significantly influence grant application behaviour and success.

a. Methodology and description of results

Grant application behaviour and success is also influenced by several individual factors of male and female academics, including:

- Personal and social responsibilities (marital status, children, domestic care, elderly care, etc.) Being married with children was found to significantly reduce women's chances to get grant funding: the US Survey of Doctoral Recipients from 1981 to 2003 found that tenure-track faculty women who were married with young children were 21% less likely than tenure-track men who are married with young children, 26% less likely than tenure-track women who were married without young children, and 19% less likely than single women without children to have their work partially or fully supported by federal grants or contracts on a year-to-year basis (Mason, Goulden and Frasch, 2010). Also, when researchers paid by grants need family leave or modification of duties, PIs are put in a very difficult position, wanting to support the individual, but also knowing that their research projects will likely suffer (ibid.). On the other hand, other studies that examined the effects of women's and men's domestic responsibilities and personal life on their publishing records do not seem to support the negative correlation between married with children status and academic productivity: e.g. married women and women with children have been found to publish more than women who are single and childless; and having young children was found to be positively related to women's productivity (Lie, 1990; Fox and Faver, 1985).

- Differences in women's attitudes, motivation, self-confidence and other characteristics due to gender socialisation (Sonnert and Holton, 2006). A recent CBU Women in Science Symposium[1] reported that top female psychologists did not approve of getting grants as a means of enhancing one's CV, and recommended a return to core values, where one applies for a grant to secure funding for quality and interesting research rather than as an end per se. The emphasis rather was on doing science well for its own sake, with the view that a good reputation would follow from this. This opinion reflects an often-reported 'opportunism' in scientists' behaviour or "mimicry in science" (Bornmann, 2011), generated by the increasing importance of publications and bibliometric indicators in research evaluation, which determines them to apply strategies that enable them to comply with bibliometric accountability and to secure funds to their own research. Other symposium speakers noted specific possible differences between men and women due to women's lower self-confidence and higher likelihood to patrol their behaviour more closely than men (e.g. women asking fewer questions in seminars or committee meetings due to marked concerns about what others may think), which may in turn have adverse effects on women's progression. Similarly, it was also noted that proportionally fewer women apply for fellowships from funding bodies such as the Wellcome Trust,

[1] 28 October 2009, see http://www.mrc-cbu.cam.ac.uk/news/WiS%20summary%20long.pdf

possibly for similar reasons, as applying for these prestigious fellowships can require extremely high levels of confidence.

- These findings converge with the so-called 'bitch avoidance' phenomenon or the women's fear of being perceived as highly assertive and confrontational, which is often seen as necessary for discussing and defending ideas forthrightly and vigorously in the search for funding, conference presentations, participation on committees and review panels, etc. (Sandrift, 2008). This is particularly visible in promotion practices, which have been found to potentially disadvantage women, if decision-makers rely on individuals putting themselves forward, rather than an even-handed scrutiny of all potential candidates. Managers should recognise that the self-image of women often makes it difficult for them to put themselves forward for promotion, as this kind of assertiveness and sense of entitlement is not part of the female schema (men are raised to expect rewards for their efforts, while women are raised to offer work and time for love).

b. Discussion of research gaps

The literature suggests that some women are impeded in their research careers by an overload of personal responsibilities that tend to inhibit their success in attaining research funding, but not so much their academic productivity. In addition, women's self image, including cultural prescriptions against assertive behaviour may also negatively affect their success, including attainment of funding. However, the literature says little about how women deal with 'role overload' from personal and social responsibilities, especially about how these issues are addressed by individual female scientists. The role of support structures is essential in minimising the negative effect of this 'role overload', but the way they helped some women to succeed, while others have failed is less explored. It would be interesting and useful to know more about the role of social support structures and impact of social policy measures on those women who have succeeded despite obstacles, as well as those who have not, in order to determine what additional steps might be undertaken.

4. The fallacy of matched gender samples: measurement methodology can obscure women's disadvantage.

a. Methodology and description of results

Scientific excellence is not a 'universal fact' or a 'natural given', or a 'supra-disciplinary' fact, but rather a social construction that takes various forms and, as such, is open to many kinds of bias, including gender-based double standards in the competence assessment processes (European Commission, 2004). According to Schilling (2007, cited in Melin, 2007), evaluation processes usually employ both numerical ratings of various kinds (also called "additive") and "intuitive" or "qualitative" evaluation methods (also called "reasoning"). The two methods are intertwined to various degrees and are both present, with different weights, in each step of the evaluation pro-

cess. The balance between additive and reasoning evaluation methods can play a key role in the assessment of female applicants (as well as in other aspects of the evaluation, like interdisciplinarity, or geographical or linguistic fairness). Starting from this premise, Melin (2007) hypothesised that the higher the degree of reasoning methods in an evaluation process, the higher the risk for women to face exclusion which is not related to their competence or the quality of the proposed project. On the other hand, the higher the degree of additive evaluation methods, the lower the risk for women to face exclusion which is not related to their competence or the quality of the proposed project. This calls for a careful use of reasoning methods and awareness of the downsides that so easily arise, potentially affecting the evaluation outcome, including applications by women.

The paradox of competitive research funding is that the playing field is relatively level, but the numbers of competing applicants are disproportionate. Male applicants are usually more numerous and more likely to hold senior positions, in contrast to the fewer women applicants in senior positions, who, moreover, are less likely to apply for funding − behaviour that may be associated with women's impending departure from academic science, contributing to the shortfall of women at the upper levels. Indeed, data from both NIH and NSF, the two agencies providing the greatest amount of funds to researchers in U.S. universities and colleges, suggest that the 'leaky pipeline' is a stubbornly persisting phenomenon. Women comprise a much larger proportion of the pre-doctoral fellowships given by these agencies than of the post-doctoral fellowships and competitive faculty grants. The drop-off in relative proportion is dramatic, with women comprising 63% and 54% of NIH and NSF's pre-doctoral awards in 2007, respectively, but just 25% and 23% of the competitive faculty grants awarded in the same year (NSF, 2008). Moreover, women who receive Ph.D.s in the sciences were found to be less likely than men to seek academic research positions − the path to cutting-edge discovery − and they were more likely to drop out before attaining tenure if they did take on a faculty post (National Academies of Sciences, 2010). This trend is also confirmed by Ley and Hamilton (2008) who found that many qualified women scientists stop applying for NIH grants in the late postdoctoral and early faculty years.

Nevertheless, when women and men are compared, they attain the same rate of success (Waisbren et al., 2008), but men gain more funding since they occupy a greater proportion of high positions from which it is possible to apply for and receive larger grants. Standard methodological procedures of matched comparisons thus obscure some of the extent of disadvantage. Such procedures compare smaller numbers of women to larger numbers of men and, by their very nature, eliminate the effect of size differences in the pools. The appearance of equality is a methodological artefact of matching procedures that allow comparisons of groups with unequal numbers. Thus, use of matched gender samples results in fallacious conclusions because of the unintended consequence of 'washing out' the most salient fact of numerical disparity. An apparently neutral methodological procedure in fact introduces a pernicious gender bias into scientific gender studies. Another procedure of comparing men and women's success in research funding recuperates some of this deficit by using the value of actual amounts received by gender. Thus, money success rate, calculated as the amount of funding allocat-

ed/amount of funding requested, has been found to be significantly lower for women (European Commission, 2009).

Women in science as a whole are disadvantaged, even though those women who are in the game do as well as men at each level (Ley and Hamilton, 2008). Thus, the key to addressing the disparity in research funding between women and men may lie one level down from the application and granting process to the hiring and promotion process. As early as 1964, Jesse Bernard found academic position "…a better predictor of productivity than sex" (Bernard, 1964). We argue that the apparent paradox of funding differences between men and women can be explained one level down by the gender disparity between men and women in senior positions and gate-keeping roles. On the other hand, the sources of the problem cannot be pushed down any further. Women now represent an equal and even higher proportion of undergraduate populations and an increasing presence in doctoral cohorts. Entry into the pipeline has improved greatly. It is the movement into the upper reaches of scientific careers that remains the blockage to productivity and to the research funding that enhances research productivity. The root cause of gender disparity in science and its consequences have been well known for a half century, but still remain to be fully and effectively addressed.

b. Discussion of research gaps

Matched comparison may hide gender differences by washing out the difference in numbers of men and women competing for funding. An absolute measure such as 'money success rate' reveals continuing disparities. These disparities are more visible at the upper levels of the academic career. Entry level issues appear to have largely been resolved, while progression issues stubbornly persist. Comparison between male and female applicant numbers at entry level and at higher academic level could help understand differences and effect, if any, of interventions.

6 Gender-specific effects of peer-review procedures

1. Gender-specific effects of peer-review procedures of national and international funding agencies are highly variable across fields and levels of analysis.

a. Methodology and description of results

The peer-review process in the evaluation of scientific work and funding applications is one of the cornerstones of science and research policy. It has been long investigated and debated, but the gender perspective of the process is a relatively recent angle of analysis. One of the major criticisms brought to the peer-review system was the hegemony of 'old boys' networks' − networks of senior scientists, most often men and seldom women, with disproportionate power over the resource allocation decision-making (Mitroff and Chubin, 1979; Wessely, 1998; Wood and Wessely, 1999). They posed a serious threat to the concept of fairness that was the very *raison d'être* of the peer-review[2].

The first major study that revealed a clear dimension of this threat by providing clear evidence of gender specific-effects in peer-review procedures was Wennerås and Wold (1997). They found significant discrimination against women in the process of awarding postdoctoral fellowships by the Swedish Medical Research Council (MRC), one of the main funding agencies for biomedical research in Sweden. MRC reviewers gave female applicants lower average scores than male applicants on all evaluation parameters, deemed women applicants to be particularly deficient in scientific competence and gave them lower scores than male applicants who displayed the same level of scientific productivity. In fact, the most productive group of female applicants was the only group of women judged to be as competent as the least productive group of male applicants. Women – but also men not known to any of the committee members – had to publish 2.5 times as much in order to receive the same score as men who were known by at least one committee member. In effect, the Wennerås and Wold study highlighted the 'remnants' of the original intention of the peer-review system, to distribute funds to persons well known to and respected by trusted peers (Kohler, 1991).

Wennerås and Wold's landmark study set in motion an extensive process of assessment of gender bias in funding mechanisms in the UK (Wellcome Trust, 1997; Grant et al., 1997), Denmark (Vestergaard and Taarnby, 1998), Finland (Peltonen, 1999), the Netherlands (Brouns, 2000a; 2000b; Van den Besselaar and Leydesdorff, 2009), Australia (Jayasinghe et al., 2001), Switzerland (Reinhart, 2009; Bornmann, Mutz and Daniel, 2008), Germany (Bornmann and

[2] On the other hand, in the US, the original intention of introducing peer review into government research funding, rather than distributing research funds to universities according to student numbers, was to insure that the funds were concentrated at elite universities, the expected source of the 'peers' (Etzkowitz, 1993).

Daniel, 2005; Bornmann, Mutz and Daniel, 2009), Spain (Canibano and Otamendi, 2009). Also, Sandstrom and Hallsten (2008) replicated the 1997 Wennerås and Wold study on the grant peer-review applications to the Medical Research Council in Sweden. Intergovernmental organisations, such as the European Molecular Biology Organisation (EMBO) have been also scrutinised (Gannon et al**,** 2001; Ledin et al., 2007). If the 1997 study of Wennerås and Wold had such a pervasive effect in Europe in the subsequent years, the gender bias in grant proposals submitted to the US National Science foundation was a concern already in the early 1990s (Broder, 1993).

A brief discussion of the results of these peer-review evaluations is presented below:

- **In the UK**, the Wellcome Trust investigated the possibility of inadvertent gender discrimination in its grant-giving practices and applications for project grants, programme grants and Senior Research Fellowships in Basic Biomedical Science, which represent the broad range of support provided by the Trust (Wellcome Trust, 1997). The study did not find evidence of women discrimination in the peer-review process: award rates were about the same for men and women, and the publication records of successful applicants were also similar. However, women project or programme grant applications were fewer than it would have been expected given the number of female biomedical researchers (the number of women applying for Senior Research Fellowships in Basic Biomedical Science was about that expected). The study also noted women's marked under-representation in senior scientific research positions, accoun-ting for just 7% of professorial-level staff in UK higher education institutes, and attributed this imbalance to the endemic sex discrimination within the scientific community (ibid.). A similar conclusion of no clear evidence of discrimination in peer-review was also found in the investigation of the UK Medical Research Council (MRC)'s grant-giving procedures (Grant et al., 1997).

- In the **Netherlands**, the study of gender bias in the 1994 assessment procedures of the two major institutions for scientific grants: the Dutch Organisation for Scientific Research (NWO) and the Royal Dutch Academy for the Sciences (KNAW) indicated different evaluations for women applicants than for male applicants: for example, had women and men equally high productivity scores, the women were more often characterized as 'good researchers', while men were described as 'brilliant researchers' (Brouns, 2000a; Brouns, 2000b). Allocation decisions were strongly correlated with the male candidates' age, number of publications and the rapidity with which they had completed their PhDs, while the success of female candidates was correlated only with age. Discrimination against women appeared to be different across disciplines. They were favoured in the Exact Sciences, but disadvantaged in the Biological and Earth Sciences, where women are more numerous. In some disciplines they received a bonus. One of the major conclusions was that gender matters, but in different ways within the different disciplines (ibid.)

- Another study (Van den Besselaar and Leydesdorff, 2009) investigated the peer-review-based grant allocation process of the Netherlands Economic and Social Science Research Council (MAGW-NWO) - the research council for the social and behavioral sciences in the Netherlands. The investigation covered applications for the years 2003, 2004 and 2005 in all social and behavioral disciplines: economics, management, psy-

chology and pedagogy, political science and public administration, sociology, anthropology, communication studies, geography, demography, and law. The study found that male and female researchers differed significantly in terms of publications, citations, and referee results. Male researchers received higher scores from referees, and the average score of the female researchers was 87% of the score of male researchers. Female researchers also scored lower on past performance indicators (about two thirds) than male researchers. Female researchers did not seem to be disadvantaged by the refereeing process since the gender differences were smaller in this dimension than in terms of past performance measurements, but the shares of female researchers appeared to be smaller than the share of women in the set of successful applicants. This was the effect of a correction of the review process results in favor of female applicants, reflecting a deliberate policy of the Council to stimulate women to pursue research careers.

- In **Australia**, the evaluation of the peer-review used to fund university research across all disciplines examined the evaluation of research proposals submitted to the Australian Research Council (ARC) in relation to characteristics of the researchers and of external reviewers (Jayasinghe et al., 2001). The reliability of the peer-reviews was found to be disappointingly low. The gender and age of a researcher and the number of researchers on a research team did not affect the probability that funding would be granted, but professors were more likely to be funded than non-professors. This was considered as an indirect form of discrimination, taking into account that women are much less represented than men at the professorial level. Also, Australian external reviewers gave lower ratings than did non-Australian reviewers, particularly those from North America. The study also provided several recommendations aimed to improve the reliability of peer-reviews: (a) no use of researcher-nominated reviewers; (b) more reviews per proposal; and (c) a smaller number of more highly selected reviewers should perform most of the reviews within each sub-discipline, thereby providing greater control over error associated with individual reviewers.

- In **Switzerland,** the peer-review procedure of biology and medicine applications to the Swiss National Science Foundation − the national science funding organisation − from the year 1998, was examined by means of the three most frequently studied criteria reliability, fairness, and validity (Reinhart, 2009). Although overall reliability was si-zeably higher for biology than for medicine, only scientific performance indicators were found as significant predictors of the funding decision, while all potential sources of bias (gender, age, nationality, and academic status of the applicant, requested amount of funding, and institutional surrounding) were non-significant predictors. The bibliometric analysis showed that the decisions of a public funding organisation for basic project-based research reflected the future publication success of applicants. The study recommended an expansion of peer-review research approaches and methodologies by increasingly focusing on process rather than outcome and by including a more diverse set of methods, e.g. content analysis, in order to advance peer-review research beyond the usual questions of reliability, fairness, and validity.

- However, a more fine-grained analysis of a larger sample of grants attributed by the Swiss National Science Foundation from 2004 to 2006 in general biology, basic biological sciences, and basic medical sciences performed by Bornmann, Mutz and Daniel (2008) found a significant gender effect only in 2006. The study revealed discipline-

dependent gender differences, particularly in life sciences, and significant gender imbalance in the allocation of grants for young researchers, and in some cases of ge-neral research grants.

- In **Germany**, Bornmann and Daniel (2005) conducted the first comprehensive study on committee peer-review for the selection of doctoral and post-doctoral research fellowships of the years 1985-2000 by the Boehringer Ingelheim Fonds (B.I.F.), a foundation for the promotion of basic research in biomedicine. The selection process of the foundation was similar for both doctoral and post-doctoral fellows, and included: application submission by the junior scientists to the foundation secretariat; forwarding of the application by the office to an independent external reviewer; reviewer's assessment of the applicant, proposed research project and institution at which the project will be conducted; reviewer's recommendation of application approval or rejection; interview of the applicant by a member of the foundation's staff, in addition to the external reviewer's assessment; submission of the application, together with the external review and the staff report on the personal interview, to the B.I.F. Board of Trustees. The Board comprised seven internationally renowned scientists, who decided on applications at each of the three annual Board meetings. Applications were accepted only if all following three selection criteria were rated positively: (1) scientific quality as demonstrated by the applicant's achievements to date, (2) originality of the proposed research project, and (3) scientific standing of the laboratory where the research would be conducted.

- Potential sources of bias were examined, including: gender, nationality, discipline, and institutional affiliation. No statistically significant influence of such sources of bias could be observed for post-doctoral fellowship applications. However, for doctoral fellowship applications, evidence of bias was found for gender, discipline and institutional affiliation, but not for nationality, suggesting that the results on the selection process of the foundation were inconsistent. Further tests undertaken to determine the extent and direction of the influence of gender, discipline and intended institutional affiliation on the Board's decisions on doctoral fellowship allocations (the so-called "predicted pro-babilities of approval and rejection", respectively) showed that the applicant's chance of receiving a scholarship decreased from an original 50% to lower levels, subject to different factors. For example, the female gender of the applicant reduced the predicted probability of receiving a scholarship from 50% to 33%. The applicant's discipline was even more important than his or her gender: If the applicant was not a biologist, but a chemist, the probability of approval declined from 50% to 25%. The opposite effect was observed for the institution affiliation: an institute of the Max Planck Society (Germany) was more highly rated rather than a German university, increasing the probability for approval by 17%. Overall, the reliability and predictive validity of the BIF's peer-review procedure, i.e., whether the foundation achieves its aim to select as fellowship recipients the best junior scientists, was found very high, in spite of some fairness problems identified, especially, the applicant's gender as a potential source of bias.

- The gender bias in the B.I.F.'s peer-review process of applications for doctoral fellowships was further explored in a subsequent analysis (Bornmann, Mutz and Daniel, 2009), which concluded that males have a distinctly greater chance than females of remaining in the "award" category and being funded in the transitions from the first (external reviewer) to the second (staff member) and from the second to the third (Board of

Trustees) evaluation stage. Findings also showed a contrary gender effect on the assessment of B.I.F. applications: an improvement in the rating from “no award” – given by the external reviewer at the first evaluation stage – to “possible award” (staff member) is more likely for female applicants than male applicants.

- In **Spain**, an assessment of the grant peer-review system used for the Ramon y Cajal Programme (Canibano and Olamendi, 2009) was performed based on the applicants’ CV. The study found that the selection process mainly relied on the research productivity of applicants and not on other variables that were not directly related with scientific excellence, such as gender, age or residence. Furthermore it suggested that electronic simulation models that successfully replicate the outcomes and rankings produced by the peer-review process could be further developed and used in the future to support and speed up the process of evaluation and selection of applicants.

- In **Sweden**, Sandstrom and Hallsten (2008) replicated the original study performed by Wennerås and Wold (1997) on the grant peer-review applications to the Medical Research Council, aiming to trace the influence of gender and conflict-of-interest on scores, controlling for performance measures (bibliometrics), academic status (professor, assistant professor, and researcher), experience (years since dissertation), faculty discipline (medicine or not), university affiliation and committee assignment. They used data on the research grant applications submitted, reviewed and acted upon during 2004. A stratified sample was drawn from the 611 proposals for new projects, 63% of which had been submitted by male applicants. A normalisation method for ranking applications was introduced that took into account the differences between committees and a normalisation of bibliometric measures by field. Nepotism (PI’s having the same affiliation as the reviewer) and gender bias were identified, suggesting that they remained a persistent problem in the Swedish grant peer-review system. The grading procedures were found to be related to gender of the applicant: the awarded score for citations per paper increased with productivity for male PIs, but not for female PIs. Instead, female PIs were rewarded the same score regardless of productivity. Male PIs appeared to be scored higher than female PIs for the impact factor, while the number of publications had a positive effect on scores for both male and female PIs. The grading procedures were also related to nepotism: PIs with reviewer affiliation always received a higher grade than applicants with no reviewer affiliation. Combining the effects of gender and nepotism, the study found that female PIs with the same affiliation as the reviewer were awarded the same grade as male PIs, whereas female PIs without the same affiliation as the reviewer were awarded a higher grade than male PIs.

- The **European Molecular Biology Organisation** (EMBO) has monitored gender bias in the selection processes for fellowships and awards since 1996, showing a success rate of women that was on average 20% lower than that of men for the Long-term Fellowships (LTF) (Gannon et al., 2001). This difference has persisted despite the selection committees' awareness of and stated commitment to gender equality, and EMBO’s receipt of an almost equal number of applications from men and women in recent years. Considering EMBO's policy that the only criterion for selection is scientific quality, the peer-review process of the organisation was recently re-assessed, testing for unconscious gender bias influences in the decisions made by the selection committee (Ledin et al., 2007). The selection committee was gender-blinded for the two rounds of applica-

tions in 2006 and the difference in success rate persisted. In the cohort of LTF applicants from 1998, there were no statistically significant differences bet-ween awarded men and women for the number of publications, total citation counts or total impact factor. However, awarded females had a statistically significant higher a-verage impact factor than awarded males when all their publications were considered, but when the average impact factor for first and last author publications alone was considered, the difference was no longer significant. This may be explained by the fact that the last author position usually belongs to the head of the research group/lab, or a senior researcher (who is more likely to be a man) who may have an important average impact factor, which may make the difference between the two impact factors not significant. In the cohort of Young Investigator Programme (YIP) applicants from 2001 and 2002, similar trends as for the LTF fellows were observed: women had published fewer papers, but the differences in the impact factor and citations per paper were not statistically significantly different between men and women. In addition, men often held higher-ranking positions, had larger grants and consequently larger laboratories, and women often had a higher teaching load than men, once again showing the impact of rank disparity on research funding success.

- **In the US**, the review of grant proposals to the Economics ProgrammeProgramme at the National Science Foundation (NSF) for the 1987-1990 fiscal years presented evidence of significant differences in the reviewing of female and male authors by male and female referees (Broder, 1993). Even when author quality was controlled by comparing ratings on the same paper, female reviewers rated female-authored papers lower than their male colleagues did. Both male and female reviewers were found to be harsher on proposals with a female PI than on proposals with a male PI. Female reviewers gave significantly worse scores to female proposers than did the male reviewers, but male proposers received the same treatment from male and female reviewers. Controlling for both paper quality and reviewer background did not eliminate the differences in reviewer ratings by gender, which supported the hypothesis that there is some bias of women reviewers against female proposals. Possible explanations for this phenomenon included a feeling of competition among women due to the small percentage of female academics in economics, which was also interpreted as a certain objectivity of women about other women. Men were easier on women, especially when they wanted to encourage the advancement of women relative to men, or when they held women to lower standards or expectations and therefore gave higher ratings when they were favourably inclined. This led to the conclusion that the policy of soliciting female reviewers for female proposals to avoid potential bias against women may actually be counterproductive for women.

The picture emerging from the evaluation studies discussed above is far from straightforward, suggesting a high variability of results by scientific discipline and level of analysis. To clarify these issues, Bornmann, Mutz and Daniel (2007) carried out a meta-analysis of 21 studies of possible gender bias covering 66 peer-review procedures in different disciplines and at different levels, which provides evidence of robust gender differences in grant award procedures. The effects in favour of men were found to be by far the most frequent, suggesting that globally, men have statistically significant greater odds of receiving grants than women by about 7%. The au-

thors did not separate postdoctoral fellowship grants and higher level research grants, but an examination of the data from the 66 individual panels showed that the most marked cases of a gender effect in favour of men concerned the fellowship schemes. However, the cause of this discrepancy is unknown. They attempted to include characteristics of the peer-review procedures into a model estimation to get some hints for potential causes. For instance, the proportions of women and men for the procedures are highly aggregated over study fields or disciplines, respectively, since women are more likely to be represented in the softer sciences in which the overall success rates are lower than those in the harder sciences (such as chemistry). Even if there were no gender differences within fields of study, aggregation over fields of study can create a strong effect ("Simpson's paradox").

Further to Bornmann, Mutz and Daniel's (2007) meta-analysis of grant awarding procedures that reported small gender differences in favour of men, Marsh et al. (2009) evaluated gender differences in peer-reviews of grant applications applying a different statistical method (juxtaposed traditional fixed- and random-effects, on the one hand, and multilevel models on the other, demonstrating important advantages to the multilevel approach) and found no gender differences for 40 (of 66) effect sizes from Bornmann, Mutz and Daniel (2007). This lack of a gender effect for grant proposals was very robust, generalizing over country, discipline, and publication year.

b. Discussion of research gaps

It is practically impossible to draw a clear picture on gender effects in the peer-review procedures used for allocation of research funding, because of their dependency on discipline, particularly in life sciences, researcher's age (young researchers are often biased), publication productivity, peer-review procedure (as well as the statistical approach, period of analysis, etc.). While some studies provide significant evidence of such effects, others do not find such effects. Most peer-review procedures are based on the submission of written applications. Oral applications are less frequent and no evidence of gender bias analysis has been available in this respect. In-depth interviews with applicants and peer-reviewers on their experience could be useful to clarify the inner workings of the peer-review process.

2. Women continue to be under-represented in gate-keeping positions, largely as a consequence of their attrition in senior positions in academia.

a. Methodology and description of results

Gate-keeping as the "fourth major role" of a scientist, in addition to that of researcher, teacher and administrator (Merton, 1973), has become as essential aspect of research funding, as gatekeepers have gained increasing power over the decision-making process in the grant distribution systems. Gatekeepers of research funding in Europe consist to a large extent of middle-aged male academics, concluded an ETAN report ten years ago (European Commission, 2000), and the situation hasn't changed much since. Women continue to be disadvantaged in gate-keeping positions, because of a persisting effect of the recognised bias of the peer-review cadre towards the elite of science and science policy organisations (Groenveld et al., 1975), in which women are systematically under-represented. In spite of a slight increase for women in the top grades of university staff in recent years, the average percentage (15%, 2004, EU-25) of women in senior academic positions in the EU Member States is considerably lower than the overall percentage for all women in all academic positions (36%), and women's under-representation in senior academic positions remains even in the fields with a high proportion of women (humanities, social sciences, biology) (European Commission, 2008). The scarcity of women in senior positions in scientific organisations inevitably means that their individual and collective voices are not heard in policy and decision-making bodies, which may lead to biased decision-making and further development of research.

The issue of women's presence in gate-keeping positions stood high on the agenda of the European Commission, which has sponsored several studies and working groups for an in-depth exploration of the phenomenon, such as:

- 'Science policies in the European Union – Promoting excellence through mainstreaming gender equality' prepared by the ETAN Expert Group set up by the Commission in 1998 (Osborn et al., 2000),
- 'National policies on women and science in Europe' prepared by the Helsinki Group on Women and Science, established by the Commission in 1999 (European Commission, 2002),
- the report by the ENWISE Expert Group on women and science in the post-communist countries 'Waste of talents: turning private struggles into a public issue. Women and Science in the ENWISE countries' (European Commission, 2003).

The WIRDEM (Women in Research Decision-Making) Expert Group established by the European Commission in October 2006 was charged with the task to review procedures for evaluating and promoting research personnel and to identify examples of good practice at national and institutional levels (European Commission, 2008). The group (17 independent experts, 14 wom-

en and 3 men, senior scientists from various disciplines) reported on the situation in their country of origin (Belgium, Estonia, Finland, France, Germany, Greece, Norway, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom). The WIRDEM Group found that women are less likely to be promoted to top positions and identified a low proportion of women on research decision-making boards, that women researchers are paid less than men on the same level (gender pay-gap), and that the more money spent on R&D, the fewer women can be found in this field. The conclusion, based on the ENWISE countries studied, was that the highest proportion of women can be found in the countries and sectors with the lowest R&D expenditure, and the lowest proportions of women are in the sectors with the highest R&D expenditure. Generally, there was a lack of awareness on gender related issues and lack of commitment to gender equality.

The 2009 EU study on the gender perspective of gate-keeping in research funding in Europe '*The Gender Challenge in Research Funding: Assessing the European National Scenes'* (European Commission, 2009) analysed the gender dynamics among applicants, recipients and gatekeepers of research funding, in funding processes, instruments and criteria, and the role of key funding organisations in promoting gender equality in research. The study re-confirmed that in most disciplines, the decision-making and other gate-keeping activities in research funding, including peer-review, continue to be dominated by men, in some cases overwhelmingly so. Also, the recruitment procedures, in particular for peer-reviewers, whose choice may be crucial, are often not clear. Although a better representation of women among gatekeepers of research funding was not found to necessarily or automatically increase the success rates of women applicants, it was deemed to have a positive effect in providing more equal access to shaping the research agenda on all levels, in improving the gender balance among gatekeepers and in recognizing women as full members of the system. An important learning effect for women on the workings of the funding and evaluation system was also noted, as well as more networking opportunities and exposure to current frontline research (see Section 4 of the report for a detailed discussion on recruitment of gatekeepers of research funding in different national settings, various gate-keeping processes related to research funding, such as evaluation processes, criteria, and eligibility).

In 2010, the EU-funded 13-country study PROMETEA explored gender patterns of scientific excellence gate-keeping, i.e. decision-makers and evaluators granting and awarding excellence, in the 27 EU member states, Serbia, the Russian Federation and Chile over the period 2005-2007 (Husu and Koskinen, 2010). The study found that only few women proceeded to a top gatekeeper position in the five areas of excellence explored (research funding, scientific publishing, conferences, prizes, and patents). In no country where data on the gender of evaluators was obtained did the proportion of women among evaluators exceed 30%. Many of these top positions were found in the highest leadership or management positions of public national research funding organisations, which raised the question of whether this was "an indication of less resistance against women's entry and career advancement in public research funding organisations than in top research in universities, industry and research institutions" (p. 137).

In boards of major national funding bodies, an equal representation of women and men was found only in the Finnish Research Council for Natural Science and Technology and in the equivalent Swedish Research Council, largely due to the fact that both in Finland and Sweden a quota is applied to reach gender balance in public bodies. In Finland, Sweden and the UK, the Research Councils also monitor success rates of applicants by gender and were also able to provide time series on this. Among the evaluators of research proposals the share of women did not exceed 30% in any of the PROMETEA countries, not even in Finland and Sweden, which both have policy targets on gender balance among evaluators. No large differences in success rates in funding applications of women and men were reported in favour of men, except from Chile, where men had clearly higher success rate. However, success rate data was not obtained from many other countries with low research intensity and large societal inequality. The scarcity of women among gate-keepers was associated to the low proportion of women among full professors in technology and engineering − only 7.2% in the EU-27, but it was also a consequence of leaving untapped a significant pool of competent engineering and technology research experts, both women and men, outside the professoriate, e.g. in industry, business and public sector.

b. Discussion of research gaps

Several studies on the presence of women in gate-keeping positions highlight their relative absence, but few of them provide satisfactory explanations of this fact. On the one hand, it should be correlated with their lesser presence in senior positions (with the notable exceptions of Finland and Sweden, where gender quotas have been instituted), and on the other, with the mechanisms of selection and promotion of women to such gate-keeping positions.

7 Gender-specific evaluation of scientific merit

1. Women scientists' research productivity continues to be inferior to that of men, although gender differences have slightly declined over time.

a. Methodology and description of results

Women scientists' lower publication outcome than men's, especially during the first decade of scientific activity, also known as the "productivity puzzle" (Cole and Zuckermann, 1984) is a long standing feature of gender disparities in academia. Cole and Zuckerman's (1984) landmark study revealed that among scientists who received doctorates in 1969-1970, women published slightly more than half (57%) as many papers as men. Men's higher academic productivity, both in terms of articles and books, in all subjects, was also confirmed by Blackburn and Fulton (1975), who identified significant differences across fields. In some subjects, such as the humanities, the difference was substantial, with men publishing two or three times as much, while in others, such as the social sciences, the gap was narrower, and the difference was in the range of 20%.

Subsequent studies confirmed the lesser productivity of women, showing that women publish on average 50-60% as many papers as men (Zuckerman, 1991). Lie (1990) found a higher productivity of academic men in Norway in some areas, with the smallest difference between male and female publication rates in the natural sciences (20%), while in other areas women published 30% to 35% less than males. In the social sciences, women were actually more productive than men. Clear discrepancies in publication rate between men and women were observed very early in the scientific careers and were found to have consequences for the subsequent citation of the scientists' work (Symonds et al., 2006). A certain decline over time of these gender differences was also reported (Xie and Shauman, 1998), with female-to-male ratio increasing from about 60% in the late 1960s to 75-80% in the late 1980s and early 1990s (see Fox, 1983; Hornig, 1987; Long, 1987; Zuckerman, 1987 for reviews of the literature on the lesser productivity of female scientists).

The explanation of this phenomenon has been a continuing challenge for social scientists. To date, "satisfactory and robust explanations of sex differences in scientific productivity remain elusive" (Long, 1992: 6). A variety of reasons have been suggested as explanatory factors: differences in personal characteristics (e.g. ability, motivation, dedication, marital status) or in educational background, family and children obligations that affect the careers of males and females in different ways, women's lower access to resources, which remains largely unfavourable to them, although a more equitable distribution of resources and structural positions to women has been noted (Xie and Shauman, 1998). Also, women's over-representation among non-publishers and their under-representation among the extremely productive (Long, 1992), the areas of specialization (Barbezat, 1987; Haberfeld and Shenhav, 1990; Ward and Grant, 1995), and the extent of research specialization (Leahey, 2005), academic rank, etc. have been

suggested to explain their lower productivity.

As a general observation, the explanations for gender differences in science generally fall into two broad categories (Levin and Stephan, 1998): (i) a deficit model, which attributes women's obstacles to career achievements to personal reasons that lie within themselves, being either innate or the result of gender socialization and cultural values (educational background, ability, creativity, motivation, and commitment to the scientific career); and (ii) a structural obstacles model, which focuses on formal or informal, legal, political, or social obstacles that exist (or previously existed) in science that differentially affect women.

b. Discussion of research gaps

Women academics' publication productivity is lower than men's, although this differs significantly by field with the notable exception of the social sciences, where female productivity is higher. A multitude of factors potentially causing this difference have been thoroughly investigated over the last three decades - it is difficult to point to specific research gaps.

2. The evidence on the gender bias of the peer-review process of women and men scientists' publications is mixed.

a. Methodology and description of results

One particular aspect related to women's lower research productivity discussed above is the gender biased assessment of scientific publications through the peer-review process, which has received increasing attention in recent years. Anonymous peer-review remains in many instances far from transparent, which may be conducive to bias within the refereeing process. The literature evidence on this aspect is rather mixed. Some studies suggest that the overall process is not sexist, but differences in acceptance rates across journals according to gender of the first author give grounds for caution (Tregenza, 2002). Others found no evidence of differences in acceptance rates among genders, nationalities, academic age, or year, or evidence of interactions among these factors (Primack et al., 2009) or evidence on gender bias on editors' ultimate decisions about manuscript publication, although the gender of editorial board members can generate differences in the recommendations about manuscript triage, turnaround time, and editors' grades assigned (Wing et al., 2010).

In the medical field, where gender imbalances are still pronounced, a massive gender imbalance was found in the journal peer-review (Heckenberg and Druml, 2010). A screening of all papers submitted to the Wiener Klinische Wochenschrift (The Middle European Journal of Medicine) between January 2001 and September 2009 found an increasing proportion of female authors between 2001 and 2007, reaching 30% and almost 50% in some specialties such as paediatrics. On the other hand, review papers or invited editorials were only rarely authored by

female researchers, a very low percentage of peer-reviewers was female − although the quality of their reviews was generally better − and only one member of the editorial board was female. No difference in the acceptance rate of papers by male and female first authors was identified, but a somewhat higher rate of papers with female first authors was subject to rapid rejection (21% vs. 16%). Papers with female first authors more often named a different corresponding author than papers with male first authors, and in most of these cases the corresponding author was a man. More than 40% of all submitted original papers, 24% of the review articles, but only 10% of the editorials had female first authors. During the years studied only 5-11% of reviewers were women, despite that the quality of their reviews was generally better than of the reviews done by men.

Double-blind reviewing was found to lead to increased acceptance rates of submitted papers where the first author is a woman scientist, but the practice of women publishing with powerful males as co-authors was found counterproductive for women, because it is often assumed that the women have not made a significant intellectual contribution. To counteract this, it is important to establish an independent publishing track record, though this is not always easy. Because first and last authorship positions tend to be far more important than other authorship positions, it is important for women (and men) to argue for an 'author contribution statement' to be included on a publication where they have made a significant contribution without achieving first- or last-author status (CBU Women in Science Symposium).

b. Discussion of research gaps

The peer-review of women and men's publications appears to be highly sensitive to the first and last author position. The practice of women publishing with powerful male colleagues seems to be a key issue in this respect, as it appears as a double-edged sword: on the one hand, the association with senior male researchers (e.g. the head of research group/lab, a senior colleague) may enhance the productivity or the visibility of women researchers, while on the other, their intellectual contribution to the publication may be overshadowed and not receive proper recognition, even when they are the first author. The suggested way out of this dilemma by establishing an independent publishing track record for women is complicated by the increasingly collaborative nature of research, especially for young researchers, who have a lot to learn from the collaboration with older colleagues. Indeed, the suggested 'author contribution statement' can better illustrate individual contributions to a joint work, although precise quantifications are difficult to achieve. Also, the influence of the research field on this co-publication practice is not sufficiently documented. More evidence on gender effects in publication peer-review procedures across research fields, institutional type (e.g. university, government research lab, industry research team, etc.) and journal procedures is needed in order to better understand the extent and determinants of the process.

8 Conclusions and policy recommendations

The analysis of literature evidence on gender disparities in research funding suggests that the phenomenon is a consequence of the long-standing and persisting gender divide in science. This is further combined with (and complicated by) social and psychological factors that determine a different propensity of men and women scientists to apply for funding, as well as the organisational culture of funding agencies. While the first of these three levels of analysis − the gender divide in science − is extensively addressed in the literature, the other two are much less substantive, which makes the integration of findings across levels a challenging exercise.

Measures and policy recommendations to encourage change depend essentially on the **assessment of the problem**:

- If the problem is **linked to the applicant** e.g. information deficits or mentoring gaps, then the focus will be on support for individuals. The support of mentoring schemes is a good policy to follow to correct the imbalance.

- If the problem is defined in terms of **insufficient women among applicants or gatekeepers**, then the focus will be on institutional transformations to stimulate women's applications and improve gender balance among the gatekeepers of research funding, including committee or panel members and reviewers, organising gender training for all involved in the funding process, establishing of quotas like in Scandinavian countries to rapidly increase the proportion of women in gate-keeping positions, setting targets, actively searching for qualified women and reviewing/revisiting appointment criteria and the definition of competence (Husu and Koskinen, 2010). Allowing applications from persons without permanent positions would potentially increase the number of female applicants, since they are more likely to lack this status (European Commission, 2009). On a deeper level, this will also need to be correlated with institutional efforts to develop more effective strategies to retain women at critical transition points, such as the juncture between postdoctoral training and independent careers (Ley and Hamilton, 2008), changes in the faculty recruitment and search process, enhancement of mentoring programmes or the promotion of differentiated career structures as alternatives to the male model.

- If the problem is the **poor/lack of a gender awareness culture**, then the focus will be on promoting specific actions and supporting structures to monitor gender equality, and encouraging research on this area, all with strong political will. The denial of or lack of interest in gender equality appeared to be one of the main sources of imba-lance in a large number of European countries. Gender monitoring and publishing of funding statistics on a regular basis, differentiated by discipline and research instrument, as well as in-depth monitoring exercises, both quantitative and qualitative, are also important (European Commission, 2009). In addition, a frequent problem is the funding agencies' unawareness of limitations in the information collected by the grant application and award data systems, with respect to gender differences. To correct that, it would be necessary to implement a data system that stores information on all grant applications and investigators, including co-investigators, at the overall agency level, rather than maintain sepa-

rate systems for each sub-agency or grant programme. Also, in order to obtain better applicant information and correlate it with the amount of funding requested/obtained by gender and other criteria, it might be useful to include in the application form key personal characteristics for each investigator (e.g. gender, race and ethnicity, institution, type of academic appointment for investigators in postsecondary education, discipline, degree, and year of degree), a record of the amount requested and awarded for each proposal and any score assigned to it by the peer-reviewers, in addition to clearly identifying initial proposals and awards, supplements that involve new funding, and amendments that involve no new funding (Hosek et al., 2005).

In conclusion, two most important steps that could be taken to reduce gender disparity in research funding are:

- **Increase women's presence in the upper levels of the academic hierarchy.** Fai-lure to address this issue vitiates measures to improve the research funding chances of female scientists. When women are equally present at all levels of academic science, they will also have the leverage to resolve remaining cultural and social issues emanating from the historic 'male model' of science. As gender, age, ethnic and other disparities are reduced and eliminated, the resources devoted to science will realise their full potential.

- Introduce an additional element to the research funding process providing funding to young researchers and to junior academics to improve their chances of success. This measure is thought to have an especially positive effect for women, mitigating the bias towards male researchers. This would provide a boost to younger women, as well as younger men, enhancing their chances of staying in academia and competing for peer-reviewed funds. As noted earlier, the widely emulated US peer-review system was designed in the early post-war to insure that researchers from leading universities distributed funds to their colleagues at other leading universities. The pre-war British system of disbursing funds according to student population was initially considered as a model for the US. The idea was discarded when it was realised that transfer of this model would tend to locate funds in large mid-western state universities. Thus, it is not surprising that the system, working as intended, favours elite senior researchers who are predominantly male. A variant of the traditional European model of associating research funds to the faculty position could be instituted for junior faculty members (rather than for senior faculty where these funds are usually allocated).

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