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GENDER DYNAMICS IN SCIENCE AND TECHNOLOGY: FROM THE "LEAKY PIPELINE" TO THE "VANISH BOX"

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ABSTRACT:

This paper discusses the "Vanish Box phenomenon" found among female scientists who migrate from academia to new occupations emerging at the intersection between science and business, like technology transfer. These occupations offer not only new career paths, but also more favourable work conditions in comparison to academic science and industrial research. The 'Vanish Box' refers to women scientists' recoupment, rather than loss, through their reinsertion into an alternative context in which their value may be realized, and possibly capitalized upon, to an even greater extent than in the original context from which they were made redundant. By delineating a dynamic, rather than static relation between the science and business institutional spheres, the 'Vanish Box' model is a more accurate representation of the gender attrition in the upper reaches of the scientific professions than either the pessimistic "leaky pipeline" view of permanent loss of women in science, or the more optimistic, but disconfirmed, "pump priming" expectation that women's rise to high positions proportionately to male scientists would naturally occur.

KEYWORDS: Vanish Box, Leaky Pipeline, Women in Science, Technology Transfer, Field Status Paradox

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"...it is NOT failure to leave academia. [...] I hate being described as someone who "leaked out of the pipeline" just because I chose not to continue doctoral study. I am not a "drip" and neither is anyone else who successfully completes an advanced degree and then successfully finds a job that they enjoy, where they can apply their critical thinking skills and research acumen to solving other kinds of problems" (Lakdawalla, 2010)

INTRODUCTION

Disproportionate numbers of women remain in low-level positions both in academia and in business, even after their presence has made itself felt for many years, inhibiting generational change. The *"pump-priming" hypothesis* that upward mobility in professional hierarchies would occur naturally once entry was assured remained unrealized and reality contradicted expectation: women in science, engineering and technology (SET) careers are lost at every educational transition stage. This loss, known as *the 'leaky pipeline'*, 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 qualified 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, although 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 (2007). 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), 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. Similarly, in ICT industry, women accounted for 46% of all leavers in the first quarter of 2002 in the UK, deepening women's drop in the ICT workforce from 27% in 1997 to 21% in 2004 (DTI 2003, 2004).

The *"pipeline" model* emphasises a linear progression through a series of staged roles within academia, with a loss of female talent at every critical transition.An unstated assumption of the 'pipeline model' is the separation of academia and industry institutional spheres by strong institutional boundaries that perpetuate a static social structure of science and technology. Moreover, the 'leaky pipeline' concept is completely opaque with regard to what happens to female scientists that leave bench science and where they go to; they are rather considered as 'lost to science'. One reason for invisibility is the perpetuation of silos and insufficient attention to the mechanisms of transition across institutional spheres. Scarce evidence documents alternative options for these women. Industry jobs in research and engineering are one such option, but the access is limited and absorption is low -

only 17.5% of women researchers in the EU and 6% of those in Japan work in the business sector, while in the US nearly two-thirds of women researchers work in industry or business (*OECD Observer* 2006). Other women chose a radical shift away from a technical, intensive, dynamic and often authoritative work life, migrating to caring occupations that deal primarily with people, with a face-to-face mode of working Griffiths (2010).

In this paper, we go beyond the 'leaky pipeline' and show that new occupations emerging at the intersection between science and economy, like technology transfer, offer a new alternative option for women scientists leaving academia, providing not only new career paths, but also more favourable work conditions in comparison to academic science and industrial research. We call this transition *"the Vanish Box phenomenon"*[3], and suggest that it supplies a suitable metaphor for the transition because it refers to the recoupment, rather than loss, of women scientists through their reinsertion into an alternative context in which their value may be realised, and possibly capitalized upon to an even greater extent than in the original context from which they were made redundant. Such women scientists find new ways of utilising their scientific, technical and relational skills in new cross-border occupational areas that translate knowledge into other socio-economically valuable forms. University technology transfer, in particular, appears to be a favourable alternative to academic science due to its high knowledge content and focus on the creation of new value for society through commercialization of scientific research.

1. THE "VANISH BOX" MODEL

The "Vanish Box" transition from the upper levels of academic science to emerging science-related professions, like technology transfer, implies a complex mix of linear and non-linear trajectories that women follow, instead of the more traditional linear career path that is commonplace among male scientists. We identify four operational phases of this transition that we call the "Vanish Box" model:

1.1. BLOCKAGES TO THE ADVANCEMENT OF WOMEN IN SCIENCE

The first phase of the "Vanish Box" model encompasses both institutional and individual blockages that systematically remove more women than men at each milestone of the academic science career:

Institutional blockages include***:***

- *A relatively inflexible academic format*, with a persistent "male model" of scientific career as the norm to which women must conform. Etzkowitz, Kemelgor and Uzzi (2000) note the "contradiction between the tenure clock and

[3]The name was inspired by the classic magic trick in which a person (usually a woman) or an object is inserted into a chamber which is then closed. When reopened, the person or object has gone. The box is closed and when reopened again, the person or object reappears, in the chamber or elsewhere in the room.

the biological clock”, i.e. frontloading of the academic career coinciding with child-bearing years, which 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 transition 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 engineering. 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 professionals Etzkowitz (1971). One explanation for this is the phenomenon of ‘territorial sex segregation’ and ‘ghettoisation’ 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, Cole and Breuer (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).

- *Peer-review and evaluation procedures* that are still largely dominated by men. However, even when women are present, they often evaluate women applicants more severely than men, perhaps to insure against being charged with favoritism, often associated with male members favoring male candidates and perhaps expecting women to favor women, when in reality the opposite is the case Broder (1993). Long’ s (2001) National Research Council Report 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.

- *Gender-bias in research funding.* Women’s lower employment status and concentration in the lower grades, in fixed-term positions, more likely to work part-time and to take career-breaks, makes them less likely than men to be eligible to apply for research grants. Even when eligible, fewer women than men apply for grants, apply for smaller numbers of grants and request smaller amounts Blake and La Valle (2000). Also, women researchers often pursue different career paths than men and have a lower likelihood of being employed in the major research universities, where most research grants are awarded Hosek et al. (2005), have lower success rate and get less grant money and years awarded than men Waisbren et al. (2008). There is also a greater likelihood of male faculty to hold an advanced research degree allowing them to request more money, obtain more favorable application scores and receive higher awards than women Gordon et al (2009).

This is further combined with (and complicated by) the organizational culture of funding agencies, frequent methodological weaknesses in the selection and approval of applications, information deficits, etc. as well as social and psychological factors that determine a different propensity of men and women scientists to apply for funding. The consequences of this male-female disparity in 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' Rossiter (1993) impedes those who are distant from the already successful. This leads to women experiencing burnout, exhaustion and a higher level of anxiety than men, as shown by a study based on 3,400 interviews with female and male professors in six countries Zimmer (2003).

Individual blockages include:

- *Women's greater likelihood than men's to leave their career in academia*, even if they had a very promising start. This has been attributed to differences in women's attitudes, motivation, self-confidence and other characteristics that are due to gender socialisation (the *differences* approach) Sonnert and Holton (2006).

- *"Bitch avoidance"* or the fear of being perceived as highly assertive and confrontational, which is often seen as necessary for discussing and defending ideas forthrightly and vigorously in an academic debate, conference presentations, participation on committees and review panels, job interviews, etc. (Anonymous, 2008).

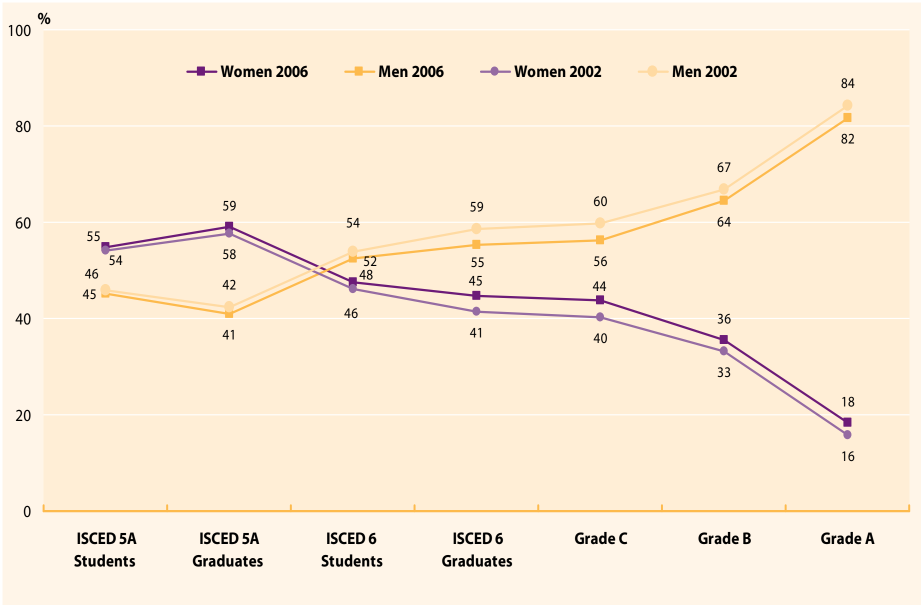
Similar blockages to women's access and promotion have also been reported for industrial research jobs, e.g. limited access to industrial jobs in science and engineering, 'old boys' networks' effect in recruitment and hiring practices, paternalism, sexual harassment, allegations of reverse discrimination, different standards for judging the work of men and women, lower salary relative to male peers, inequitable job assignments, other aspects of a male-oriented culture that are hostile to women, limited opportunities for advancement in management positions, limited access to mentors, poor child care facilities Office for Science and Engineering Personnel (1994); AAAS/L'Oréal (2010).

1.2. Disappearance Into A "Reserve Army" [4] Of Women In Science

The second phase of the model emerges as a consequence of the blockages to the advancement of women in academic science and industry discussed above. At each key transition point in the academic career women leave scientific fields disproportionately to men (see the 'scissors diagram in Fig.1 below), which is both a waste of human resources and a serious obstacle to the development of sciences and society as a whole. For example, in the European Union the proportion of female students (55%) and graduates (59%) exceeds that of male students, but men outnumber women among PhD students and graduates, and at the full professor level, women become least represented (from 27% in humanities and social sciences to 7.2% in engineering and technology). Women remain a minority in scientific research, accounting for 30% of EU researchers in 2006[5] (European Commission, 2009). In the US, for over 30 years, women accounted for over 30% of PhDs in social sciences and behavioral sciences and over 20% in the life sciences, but at the top research institutions, only 15.4% of the full professors in the social and behavioral sciences and 14.8% in the life sciences are women—and these are the only fields in science and engineering where the proportion of women reaches into the double digits National Academies of Sciences (2007).

[4]We use the term 'reserve army' as an adaptation of Marx's (1867) concept of a surplus population of unemployed workers to gender relations where it refers to the underemployment of highly skilled women.
[5]However, wide variations can be noted between countries. At the top of the country ranking, there are the Baltic States but also Bulgaria, Croatia, Portugal, Romania, and Slovakia, all of which have more than 40% of women in their research population. Sixteen other EU countries have a proportion of female researchers of between 26% and 39%. In four European countries, the proportion of women researchers drops at 25% or less European Commission (2009).

FIGURE 1. PROPORTIONS OF MEN AND WOMEN IN A TYPICAL ACADEMIC CAREER, STUDENTS AND ACADEMIC STAFF, EU-27, 2002/2006



<u>Definition of grades</u>:
A: *The single highest grade/post at which research is normally conducted.*
B: *Researchers working in positions not as senior as top position (A) but more senior than newly qualified PhD holders.*
C: *The first grade/post into which a newly qualified PhD graduate would normally be recruited.*
ISCED 5A: *Tertiary programmes to provide sufficient qualifications to enter into advanced research programmes & professions with high skills requirements.*
ISCED 6: *Tertiary programmes which lead to an advanced research qualification (PhD).*

Source: European Commission (2009) based on Education Statistics (Eurostat); WiS database (DG Research); Higher Education Authority for Ireland (Grade A)[6].

Marginalization and underutilization of women creates a "reserve army" of un- and underemployed female scientists. In wartime, when there was a pressing need for scientific 'manpower' and not enough men were available, this 'reserve army' was called upon to fill research posts, e.g. the US and UK during the 2nd World War. For

[6]***Exceptions to the reference year (s):*** **ISCED 5A Graduates 2002**: DK (2003), FR (2003); **ISCED 6 Graduates 2006**: IT (2004); **2002**: DK (2003), FR (2003), RO (2003); **WiS 2006**: EE (2004), IE (Grade A: 2002-2003), EL (2000), MT (2004), PT (2003), SI (2007), SK (2007), FI (2007); **2002**: IE (2004), EL (1999), NL (2003), UK (2003)
Data unavailable: **ISCED 6 students 2006**: DE, LU; **2002**: DE, LU, RO, SI; **ISCED 5A - 6 Graduates** LU; **WiS 2002**: LU, IE (2004 -no grade A); Grade C unavailable: BG, RO (included in B). ***Break in series:*** CZ (2005); ***Provisional data:*** ES; ***Data estimated:*** EU-27 (by DG Research) for WiS, ISCED 6 students, ISCED 5A-6 graduates; SI Head count (Grades A, B, C)

example, Maria Goeppert Mayer's best employment prior to the Second World War was at Sarah Lawrence, a small teaching college for women, but at the onset of the war, she was hired into the Manhattan project laboratory at Columbia University, and later won the Nobel prize. Another example is women's rise in science in Portugal during the post-war conflicts of African decolonization Stolte-Heiskanen (1991). In times of economic depression, the 'reserve army' has also included male scientists. During the 1930's, the only available employment for many research-oriented PhDs was in small teaching colleges. At the inception of WWII, these men were among the first recruited to new war-time research labs like MIT's "Rad Lab" for radar development Leslie (1993). At present, underutilization is exemplified by many highly qualified women who, for reasons most often related to 'glass ceiling', discrimination or work-life balance, leave research universities and find positions in other environments, such as teaching colleges, where they try to pursue their research interests in circumstances where significant support is largely lacking. Another option is to create research associate positions for themselves at research universities to obtain research funds while working part-time. Other women scientists give up the bench completely, but remain connected to science, leaving open possibilities for return, although return is often difficult, if not impossible to achieve, due to a variety of reasons (e.g. inflexibility of traditional academic career paths, developments in the new career, work-life issues, etc.)

1.3. Emergence Of A New Occupation

The third phase in the model is a change in economic and social conditions that creates the premises for a new occupation or profession. The change can be determined by a crisis situation, like war, or by 'natural' market or societal evolution. An example of change emerging in times of crisis was the necessity to undertake secret ballistics research for the US Army during WWII, when a group of female mathematicians, known as the 'women computers' were hired to this purpose and later went on to serve as the programmers of ENIAC, the first electronic computer[7]. In the 1940s, women were the very first programmers, or 'coders' - a low-status skilled work for women in a division of labor giving the presumably highest skilled work to the high-status male scientists and engineers, the conceptualisers and builders of computing machines. It took a while before it was realized that the interface with the machines was not trivial and indeed required the invention of a new highly-skilled specialty: programming. Some of the women coders pursued professional computing careers and became successful programmers, and even leaders in the programming profession, like Grace Hopper and Betty Holberton of UNIVAC, and Ida Rhodes and Gertrude Blanche of the National Bureau of Standards. However, their prominence in programming started to wane in the 1950s, as business applications were surpassing scientific applications. Programmers became increasingly sought after in the emerging computer manufacturing industry that was seeking to meet the expanding needs for business

[7]The story of 'women computers' is little known, and the *'Top Secret Rosies: The Female Computers of WWII'* documentary, shown in March 2011 at the Computer History Museum in California does a laudable job in bringing it to public attention.
See http://www.topsecretrosies.com/Top_Secret_Rosies/Home.html for details.

applications. Increasing numbers of males entered the programming profession, soon exceeding the number of female coders who had become programmers.

Another example of change that can be considered as a ‘natural’ market and societal evolution is the more recent transition from Industrial to Knowledge Society, which brought forth new scientific fields with potential for commercial exploitation such as biotechnology and information technology. This potential is realised through a series of technology transfer (TT) organizations, including science parks, incubators and TT offices that aim to close the still present gap between basic and applied knowledge through new research translation mechanisms. The emergence of TT arises thus from a “tectonic shift” in the relationship between science and the economy, offering the opportunity to create new technologies and enterprises, as well as new occupations and professions Etzkowitz (2008). The expansion of TT professions also reflects shifting TT professional status from peripheral support to core competencies in corporations, government labs and universities, as a multidisciplinary knowledge-based profession that inspires new research ideas and receives recognition in the economy.

In the following we shall focus on university TT as an example of an emerging occupation that has led to significant opportunities for female scientists and technologists in recent years. TT is the process of transferring scientific findings at various stages of development from university to industry etc., for the purpose of further development and commercialization. The process typically includes: (i) identifying new technologies; (ii) protecting technologies through patents and copyrights; and (iii) identifying development and commercialization strategies, such as marketing and licensing to existing private sector companies or creating new start-up companies based on the technology. TT bridges the gap between invention and innovation and fosters the creation of new economic activity. The field is in an incipient stage of professional development and is only beginning to be viewed as an independent career path.

The TT profession emerged in academia in response to recognition by universities that it was in their interest and the public interest to regulate the introduction into the market of discoveries made on campus to insure ethical manufacture in the early 20th century Bliss (1984); Apple (1989). Heightened awareness of financial potential arose from business people searching campuses for marketable inventions. In response, some individual faculty inventors and their universities decided to capture rents from these discoveries. This led to the introduction of patenting and marketing activities in external organisations to the universities, such as Research Corporation, which experienced a specific evolution towards internalisation[8]. Personnel drawn from university research contract offices and legal offices initially staffed the operations of the internalised university TT offices..

[8]Universities that originally wanted to keep TT activities at arms’ length to limit the perception they were too involved in business activities, like MIT, eventually internalized TT to have more direct control of their relation with industry. For example, MIT, having multiple relationships with IBM, did not want to be involved in the all-out legal battle with IBM over patent rights that Research Corporation was pursuing on their behalf Etzkowitz (2002)

The remit of TT offices expanded thus significantly from the 'traditional' TT through publications, student education and extension programs, to TT through intellectual property (IP) and the activities related to its disclosure, protection, and licensing operations, in at least two directions: (1) taking an active role in marketing, identifying users for inventions and potential licenses for IP rights; and (2) developing the capacity of creating organizations, typically start-up firms, to develop and market an invention. In this case, IP may be licensed to a firm that may involve the inventor in some capacity, from CEO to scientific adviser, and may involve the university in a more extensive role as investor as well as licensor Ensley and Hmieleski (2005). While the primary motive of the TT offices is to protect and market the university's intellectual property, secondary motives include promotion of technological diffusion and securing additional research funding for the university, via royalties, licensing fees, and sponsored research agreements Siegel et al. (2003), sensitizing researchers to the commercial implications of their investigations, assistance in new business development, participation in regional development organisations and formulating policies to promote and regulate commercialisation activities.

University TT offices are usually relatively small-sized organizations that evolved from one and two person operations to several dozens of persons, organized with functional specializations by technical field and transfer modality. They may offer apprenticeship training opportunities, a modest career ladder and the opportunity to follow transfer cases from inception to completion. Early university TT professionals were typically former academic research administrators, university legal staff or industrial researchers who were hired into the university from firms on the premise that they could establish links with local high tech industry. Now, young persons, with scientific, technical, law and business degrees, at various levels, may enter the field directly. Having done so, many feel the need to supplement scientific or technical training with a business degree, patent law training or vice versa, with scientific and technical expertise. In recent years, the various science/business interface fields have developed some of the characteristics of independent professions, with professional associations, training programmes and academic degrees.

1.4. REAPPEARANCE IN THE NEW OCCUPATION

The fourth phase is the 'recall of the reserve army' - the reappearance of the 'disappeared' women from academic science in the new occupations emerging as a result of the changes discussed above. University TT is such a new profession where many positions were filled by un- or underemployed PhD scientists, most often women (e.g. the case of academic TT in the UK during the mid '90's[9]). Female scientists have also moved into the new firms that have opened up at the intersection of academia and business, often through the support of TT offices.

The representation of female scientists in TT institutions has been only very little

[9]First author's interview with Douglas Robertson, Director of Business Development and Regional Affairs, Newcastle University, 2006

examined, with a few notable exceptions (see Smith-Doerr (2004); Ahl (2004) for a discussion of the state-of-the-art in the US and Europe). Elsewhere Ranga et al. (2008) we report several features of university TT that are amenable to women's participation and success, such as:

- ***Gender-neutral status of the field***: our findings identified university TT as a field populated relatively equally by both sexes, where a movement toward gender equality was gaining ground. Being female generated neither advantages nor disadvantages - a situation which was equally applicable to men.

- ***Flexible working practice and good work-life balances, high degree of autonomy and freedom in employees' approach to their work***, ***family-friendly environment.*** Even where we found evidence of long working hours, this was not done at a cost to family life and was performed as a result of work necessity rather than any culture of 'presenteeism'. The sector was characterised by a 'work hard' culture rather than a 'long hours' culture.

- ***Recruitment and promotion carried out on the basis of 'the best person for the job'***. Not only were women employed in equal numbers to men, but a high proportion of women were found in senior positions, which refutes the existence of a 'glass ceiling' within the sector. While 'old boy networks' proliferate in other sectors, in the university TT sector such networks were notably absent. Women's only networks appear to be generic in nature having a geographic or institutional focus or targeted at a wide range of 'business women'.

- ***Positive perception of TT as a field with multiple benefits to society:*** many TT employees felt they were active in a field that brings benefits to society, thought they were using their scientific knowledge in a context that provides high interaction with people from a range of organizations.

- ***Broad range of professional backgrounds and expertise, emphasis on team working.*** TT personnel usually have a broad range of formal qualifications that allows them to "span the boundary between science and the translation of it", which requires abilities to combine many formerly distinct areas of work. TT personnel need to be familiar with science and the public understanding of science, but also with business management and administration funding mechanisms and legislation. The boundary spanning roles may also be easier for a person that has working history in both business and science. Team-working often enhances this accumulation of individual expertise and creates better premises for success,

- ***Limited career advancement opportunities:*** in general, the ability of TT organizations to offer continuous career paths is limited by their relatively small size and flat structure, in addition to the early development stage of the TT field, which was often considered not to be mature enough to offer a career.

As certain ancillary tasks relating to the economic and social uses of science become more important, so do the holders of those positions. Women scientists' 'reappearance' in TT makes them increasingly important players in innovation, as the intermediation among science and industry institutional spheres becomes more significant as the basis of future economic development. While science and business have traditionally been male preserves, they increasingly require relational skills especially as traditional hierarchies are replaced by lateral organizations. Interface professions, with their requirements for negotiating across boundaries, draw even more strongly upon resources associated with the traditional female role.

CONCLUSION

Preserving women's advancement

Through its non-linear dynamics, the "Vanish Box phenomenon" appears as a transitional phase on the path to gender equality through creation of new career opportunities in potentially gender-neutral areas in periods of social change in which new occupations and professions requiring scientific and technical expertise (e.g. TT, science journalism, science diplomacy, etc.) appear, absorbing un- or underutilized women.

In contrast to the '"leaky pipeline' that presumes a static social structure of science and technology and narrowly focuses attention on academia and how to eliminate "leaks" or "drips", the 'Vanish Box" describes a dynamic social structure of science and technology, where the "leaks" or "drips" are not necessarily a failure, but a re-direction of scientific potential and talent to other economic and socially valuable areas. Just as "brain drain" has been found to be not an entirely negative phenomenon, as the scientific diaspora is able to contribute to advance in the home country, the "Vanish Box" suggests a similar potential.

However, just because of its dynamic nature, this re-direction is not a simple, straightforward phenomenon. The TT field is relatively new and many of its organizational and structural features are still in transition, including its gender balance. For example, as a relatively low-status field in the US a few decades ago, TT was heavily populated by women who attained leadership positions. More recently, more men have entered the field, often encouraged by women who viewed men's presence as a sign that the prestige of the profession was increasing. Ironically, as women were pushed down in male-dominated academic science, men appear to be pushed up in the new, female-dominated TT occupations. Is this changing gender balance in TT likely to lead to the gradual displacement of women, as it happened with the women programmers after World War II? Are the gender equality benefits that seem to have been attained in the university TT profession at risk because of this transition?

These findings are interesting to explore further in the light of the gender queuing theory, or the theory of job queues and gender queues Reskin and Roos (1990), which postulates that jobs become more male-dominated as they become more desirable: employers tend to value men over women in hiring and promotion (forming a gender queue), and workers will take the best possible job (in their rankings of jobs in job queues). In addition, the organizational context of work may provide further insights to gender balance and possible bias. In the TT case, it may be relevant to assess whether men entering the field experience privilege in employment practices, or whether organizational characteristics disrupt or encourage such privilege and formations of gender queues.

The changing gender balance and declining representation of women in high-status roles as the status of the field rises is a complex problem, with wide implications for innovation, employment and the optimal use of social capital, more broadly. We argue that one key reason for women's under-representation in high-status SET positions is the *"field status paradox":* when the status of a field is low, women will be found in large numbers; as the status increases, the number of women declines. The reverse situation is also possible: when the status and pay declines, women are allowed into the field to fill the vacancies created by men's departure to more financially-rewarding jobs. Either way women lose.

The 'field status paradox' is a reflection of the long-standing and persisting gender divide in science and technology, that may be further combined with (and complicated by) organizational culture, selection and promotion criteria, social stereotypes deeply embedded in individuals' minds starting from an early age, poor or lack of a gender awareness culture. Therefore, actions for change should focus on each of these levels. Merely getting an increasing number of women in a field does not mean that the problem is solved. Indeed, more women entering a field may be the result of a specific feature of the field that makes it less attractive to men, rather than a sign of increasing attractiveness of work conditions for women. An example is the experience in academic computer science in Mexico. As salaries stayed low, men left for industry and women were allowed into academic jobs Etzkowitz, Kemelgor and Uzzi (2000). Similarly, the Biological Sciences Division at Lund University in Sweden in early 2002 saw a great increase in the number of women going into veterinary science, at a time when this discipline was declining in status in the country[10]. The seeming indicator of a solution can also be an indicator of a continuing problem.

There are signs that women may hold their own in the new TT field, thus possibly breaking the heretofore seemingly inexorable link between field status and gender, e.g. the election of a woman as president elect of the Association of University Technology Managers (AUTM), after a string of male presidents in recent years, and a Women's Network Special Interest Group (SIG) was established by AUTM, in response to the increasing visibility of gender issues in TT. We can also mention here the fact that AUTM recently initiated the recording of their members' gender, for the first time, after a long period where the gender issue was invisible. Another example is several women having attained directorships of TT offices at leading US universities (Stanford, MIT).

However, if the progress towards gender equality attained in TT is to be continued and preserved, specific actions and supporting structures may be necessary, such as promoting women role models, monitoring gender equality and encouraging research in this area. At the institutional level, transparent and objective recruitment, retention and assessment are essential. At the cultural level, a change in taken-for-granted social norms is much needed, removing negative stereotypes about women

[10]Personal communication of the Dean of Biological Sciences to first author.

that can hinder their performance, depress their self-assessments of ability, and bias the evaluations made of them by key decision makers, funneling them away from degrees and careers in male-dominated occupations Correll (2011). Most importantly, the relationship between family and work creates a series of interrelated dilemmas for women that must be addressed in a comprehensive fashion. Otherwise, if previous patterns repeat themselves in the newly-created fields where women have gained significant status, a new “leaky pipeline” could be created, in which women lose their gains, replicating a “field status paradox”.

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