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Women Scientists in the Leaking Pipeline: Barriers to the Commercialisation of Scientific Knowledge by Women

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Abstract

The modern literature explaining the under-representation of women in science often relate to the shortage of women 'in the pipeline'. The pipeline flows from one stage to another, and the flow of women diminishes over the stages. Speaking of the stages of career during which women scientists 'leak' the most, the commercialisation of science as one of the ultimate stages should be taken into consideration. The primary objective of this paper is to discuss barriers to the commercialisation of scientific knowledge by women. The collected extensive literature allows to pinpoint the reason why scientific career or success fail to provide a springboard for the practical use of knowledge. Analysed research, indicate only some of the barriers, meanwhile this paper collects most of 'experienced' obstacles and shows them in 'leaking pipeline' context. Barriers originate in at least two sources: women themselves and external factors beyond women's control.

Keywords: women scientists; academic entrepreneurship; female entrepreneurship; leaking pipeline; technology transfer.

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Introduction

One of the most important challenges that European economies have to tackle is the capacity to transform scientific knowledge and technological achievements into commercial successes. The close synergy between science and business is tantamount to a high economic development of a country. Business experience may generate ideas for new research, and for universities strong links with business can be a source of money, as well as prestige and inspiration in terms of scientific pursuits and programme-building. Technology transfer from science to business is becoming the bedrock for building a knowledge-based economy.

Increasingly, a laboratory scientists is being replaced by a modern scientist-entrepreneur who is successful in commercially implementing his or her research projects. Yet, the fraternity of scientists commercializing science is dominated by men. What is that? What makes women less likely to engage in business ventures that might ensue from their research? To discuss barriers to the commercialisation of scientific knowledge by women is the main aim of this paper.

In elaborating such barriers faced by women scientists, I will use the metaphor of the leaking pipeline. Assuming that the commercialisation of knowledge is the crowning achievement of a scientific career, I will demonstrate that, as it is also the case at the earlier stages of scholarly development, the leaking pipe occurs also at this point. This is attributable to the fact that barriers that women encounter on the way to the commercialisation of science cause an additional "leakage" at the end of the pipeline.

In scholarly discourse, the under-representation of women in science is often attributed to the shortage of women 'in the pipeline.' The pipeline is made of distinct segments corresponding to educational stages (e.g. elementary school, middle school, high school, college, etc.). The pipeline flows from one stage to another, and the flow (or 'supply') of girls/women diminishes over the stages. Berryman (1983) was one on the first who used the metaphor of pipeline to understand different ways to pursue a scientific career by women and men.

Women leak from the pipeline by choosing other options (Ahuja 2002; Fayerherm and Vick 2005) or failing to progress (Lemons and Parzinger 2001; Michie and Nelson 2006). If there is a lack of supply at one stage, or a leakage at some point, it naturally explains the shortage in subsequent stages. Other authors note that academic careers have traditionally been conceptualized as pipelines, through which young scholars move continuously from the graduate school to tenure-track positions (Wolfinger, Mason, and Goulden 2006). It suggests that the ultimate goal in science should be tenure-track positions. I thinks it is justified to recognize yet another stage of this process, namely the commercialisation or technology transfer.

All in all, the leaky educational pipeline, going back as early as childhood, is partly responsible for the uneven number of men and women in faculty positions at universities across the world. Those leakages are well documented in relation to STEM (science, technology, engineering and mathematics) (Varmaa and Hahnb 2008; Cronin and Roger 1999; Blickenstaff 2005) or IT (Soe and Yakura 2008; Randall, Price, and Reichgelt 2003; Margolis, Fisher, and Miller 2000; Wright 1997; Camp 1997) as well as biology (Luckenbill-Edds 2002).

Speaking of the stages of career during which women "leak" the most, the commercialisation of science as one of the ultimate stages should be taken into consideration. This stage is seen as the culmination of the scientist's career, who first makes every effort to achieve remarkable scientific results to be able to commercialise them afterwards.

A closer look at the barriers to the commercialisation of science by women may help furnish the answer to the question about the causes of women drain at the earlier levels of the pipeline.

Another theory that might prove useful in explaining the cause of under-representation of women at the top levels of the scientific career is the theory of human capital. Among the main contributors to the theory, there was Gary Becker (1975), who investigated the reasons for huge wage differences in the U.S. labour market. He found that some employees decided to invest in themselves (so-called "human investment") to raise the level of their professional competence, acquire or improve practical skills, or to get any further training. As follows, the inequalities in achieving the successive career levels are in a way related to the size of human capital resources, which differ for individuals. This differentiation is particularly conspicuous among men and women. Employees achieve different levels of education and display different skills and levels of competence, which translates into different levels of productivity (as shown by a number of publications in IF high-ranking journals, the number of citations, received grants, etc.), and this results in inequalities in promotion to the ranks science.

The theory of human capital propounds that women are at a disadvantage in science is due to a lower human capital resource. It manifests itself in a lower level of qualification and skills ascribable to employment interruptions due to, for example, family leaves. Over this time, their knowledge and professional experience becomes out-of-date or is most of it is forgotten, while their male colleagues keep increasing their productivity. Consequently, on their return to work, women cannot hope for the same career path as men (such

as a permanent contract of employment, tenure-track or the prospects for commercializing their knowledge).

The theory of human capital assumes that the human capital resources are accumulated through the employee's individual choices in the past (for women, it is the decision to give birth to and raise a child). These choices make women less capable of being promoted in science.

This paper aims to pinpoint the reason why scientific career or success fail to provide a springboard for the practical use of knowledge (or why this is insufficient), such as running a business, and what obstacles women scientists face in this process compared with men. Such barriers probably typify all the stages of female scientists' career, but their impact is particularly discernible at the stage of knowledge commercialisation.

Women scientists in business

The author has selected several examples of research done in different countries and has made a comparative analysis. These studies showed different barriers to the commercialization of science. The latest knowledge on this subject (women scientists in business) concentrates on three areas: women in science, female entrepreneurship and academic entrepreneurship. Although the research literature abounds in sources on the subject, also with regard to the aforesaid areas, not much critique has been published so far on the commercial use of scientific knowledge by women.

There are many types of activities undertaken by academics and related to entrepreneurship. In particular, consulting, contract research, large-scale science projects, external teaching, testing, patenting/licensing, or spin-offs (the most advanced form of entrepreneurship).

To start with, it must be underlined that there is a significant imbalance between the number of female and male scientists involved in the commercial use of science, with women being particularly disadvantaged here.

What do we know about women scientists in business? First of all, it must be admitted that women's participation in commercialisation activities is found to be greater in industry than in the academia/universities (Whittington, Smith-Doerr 2004). Second of all, women are more likely to patent in flattering, more flexible, network-based organizational structures than in hierarchical organizations in the academia and the industry (Whittington, Smith-Doerr 2008). But surprisingly enough, women scientists within the academia are found to be as likely to engage in commercialisation activities as their male colleagues (Corley and Gauhan 2004). Taking into account productivity, it must be admitted that women yield fewer patents than their male counterparts. But although female scientists participate and produce less, the quality and impact of their patents is equal or superior to that of male scientists (Whittington and Smith-Doerr 2004). Women are a minority among those who commercialise knowledge. There are fewer women than men working over the same time at universities and in the industry. As a consequence, there are fewer women than men to establish spin-offs.

The barriers to the commercialisation of scientific knowledge by women

What are the barriers that women scientists face in entrepreneurship? First of all, there are obstacles common both for women and men; among them, the most prominent seems the reluctance of the scientific community to transform universities into companies and researchers into businessmen. Scientists admit that no one can reconcile being a teacher, researcher, leader, and also entrepreneur at the same time (Fältholm, Abrahamsson, and Källhammer 2010).

On the other hand, they experience being envied by their colleagues, whose activity is focused only on research and they are unable to guide their career towards commercialisation. This is true of to both women and men.

And probably the most important observation is that not all provinces of science can be commercialised to the same extent (or in the same way). In fact, only a very small portion of research is prone to this process. It is far easier in industry, engineering and technology than in the humanities or social sciences. We have to look at those fields of science from an entrepreneurship point of view. Commercialisation needs money. It is raised mostly in the private sector. The sponsor's first (and most important) criterion when choosing to work with a scientist is the financial viability. If not sure of the profitability of a project, mentors/sponsors register little interest in such a collaboration. This situation occurs more frequently in the humanities or social sciences than in STEM. There is no doubt about it.

Such barriers make no difference between women and men - they are affected equally. Below, some barriers will be discussed that occur only in the case of women scientists.

Stereotypes

A stereotype is a popular belief held about an individual. Charles E. Hurst wrote (2006) that "one reason for stereotypes is the lack of personal, concrete familiarity that individuals have with persons in other racial or ethnic groups. Lack of familiarity encourages the lumping together of unknown individuals." One of the strongest stereotypes related to fe-

male entrepreneurs is that they need "special support." For example, one of the European Commission reports on female entrepreneurship reads:

Women frequently lack the necessary confidence and skills to successfully start and run a business. (Young Entrepreneurs, Women Entrepreneurs, Co-Entrepreneurs and Ethnic Minority Entrepreneurs in the European Union and Central and Eastern Europe 2000; Green Paper - Entrepreneurship in Europe 2003).

The stereotypes about women entrepreneurs translate into their personalized evaluation by potential partners. Therefore, it is so difficult for women to break out of the cage of mistrust created by prejudices.

The next stereotype that is worth mentioned is about creating special linguistic categories just for women, for example, "women entrepreneurs;" while the literature and research on the subject omits to mention "men entrepreneurs," there are only entrepreneurs (it is implicitly ascribed to men) (Fältholm, Abrahamsson, and Källhammer 2010).

This stereotype is strongly linked to another one: the definition of a "real entrepreneur." Who can be called the real entrepreneur? Only men. Even if women commercialise their knowledge (for example, "sell" services, have contracted courses, etc.), it has not being seen as genuine entrepreneurship. We can even find a term which refers to that as the "second order type of entrepreneurship" (Fältholm, Abrahamsson, and Källhammer 2010).

An imminent consequence of the above stereotypes is unequal treatment of women entrepreneurs. However, this continued reiteration that women are weaker or less capable and, therefore, should be approached differently (gently) argues against them in the long run. Some authors (Lewis 2006) see it as "stigmatized identity" (stigmatization). This could suggest that women are not, unlike men, so much interested in innovation and technology transfer, due to their limited self-promotion skills, etc. Bearing that in mind, women firmly oppose the employment of different evaluation criteria in assessing their work. Ahl (2006) and de Bruin et al. (2007) point out that highlighting the obstacles faced by women might preserve and reinforce the existing unequal gender structures in organizations.

In other words, there is a substantial risk that the interventions aimed at supporting women entrepreneurs instead of encouraging structural changes promote and reinforce the image of the successful male entrepreneur (Fältholm, Abrahamsson, and Källhammer 2010).

And finally, there are stereotypes and assumptions among male supervisors that women are unwilling or unable to travel, relocate or work irregular hours, which excludes them from consideration for critical developmental opportunities (Catalyst 1992). This is also strongly related to the conviction that employing women is not cost-effective, especially young women who are likely to ask for maternity leave in a foreseeable future.

Barriers related to female behaviour

The other group of barriers to be discussed are those related to female behaviour. First of all, it needs to be stressed that women have less access to key resources because they are women. Women researchers often feel that they have less access to important networks and R&D, which explains their disadvantage in obtaining external funding and being published. Networking is necessary to seek funding opportunities; exclusion from informal networks and channels of communication means lack of understanding of organizational policies and means of approaching mentors or sponsors. Social networks play an important role in fostering commercial activity among the faculty. They come in play, for example, in the formation of scientific advisory boards and access to venture capitalists. We can hypothesize that women are excluded from academic-entrepreneurial networks (Fältholm, Abrahamsson, and Källhammer 2010, Renzulli, Howard, and Moody 2000; Stephan, Black, and Chang 2007).

Why do women not create their own networks instead? Because if they do so, they are often seen as powerless, meanwhile men continue to establish and participate in increasingly powerful informal networks (proper networks versus artificial networks), promoting the distribution of influence of the male successful academic and entrepreneur within certain fields of research (Fältholm, Abrahamsson, and Källhammer 2010).

Another obstacle is associated with "requesting". Women are not requested. For many academic scientists, commercial opportunities arise from being requested by others: colleagues, former students or venture firms, to participate in an entrepreneurial activity. But women are not requested to do so. Why is that? First, women may be less effective in selling their research results to others and thus getting national and international attention that such a research may generate. Second, women are less likely to be selected for the type of honours that make them attractive to deal makers (Stephan and El-Ganainy 2007). But on the other hand, women themselves do not make requests. Women faculty members sometimes explain their lack of entrepreneurial activity by saying that "they are not invited" to participate in a startup activity or they do not wish to disturb something, etc. (Babcock and Laschever 2003).

It should not be overlooked that there are also women who do not want to commercialise science. They prefer to focus on strictly scientific activities. It has a material impact on women's limited involvement in commercialisation. Women approach the commercialisation of their scientific knowledge as something secondary (temporary) to their "proper" scientific career, which is given priority. While women often consider working in technology transfer as temporary in nature and "second best" when compared to a career in science, men approach their career with an entrepreneurial spirit (Achatz, Fuchs, Kleinert, and Rossmann 2009).

When considering psychological factors, it is important to note that women prefer to work with other women. They are less likely to collaborate with men-colleagues who get involved in commercialisation. Researchers prefer to liaise with researchers of the same sex. Moreover, friendship in the research world is gender-based, women display a lower capacity for associating with colleagues who are patenting, commercialising or have contacts with the industry (Ferber and Teiman 1980, McDowell and Kiholm-Smith 1992; Murray and Graham 2006).

In most cases, a researcher is independent in his or her decision on the subject of the research. Such a choice may prove to be a limitation to commercialisation. Unlike men, women choose the types of research that do not lend themselves easily to commercialisation. As they begin the research, they do not think about the prospects for commercialisation just like men do (Stephan and El-Ganainy 2007, Murray 2004). This may be related to women's reluctance to take risks, which is inextricable from undertaking large-scale and complex research. This risk aversion, however, is mainly associated with financial decision-making. Women are not enthusiastic about managing very expensive projects as they fear potential failure (Jianakoplos and Bernasek, 1998).

Another, rather intrinsic barrier is the natural female disinclination to rivalry and competition. As put by Muriel Niederle and Lise Vesterlund (2007):

In an experiment in which women and men were allowed to choose between a winner-take-all tournament form of compensation or a piece rate form of compensation for solving problems, 75% of the men chose the winner-take-all scheme while only 35% of the women did so.

Studies show that entrepreneurship in science requires the ability to "sell" science. To be able to engage in successful self-promotion is always helpful. One reason that women engage less in an entrepreneurial activity than men is that they may be less predisposed towards "selling" their pursued research (Murray and Graham 2005).

Particularly noteworthy, when speaking of the barriers encountered by women scientists, are flexible forms of employment. In most countries under the Western cultural influence, there are institutionally sanctioned possibilities of combining professional and family life through flexible forms of employment - the same for men and women (Rosa and Dawson 2006). However, as in Germany, although the convenience of work-life balance is equally available to both sexes, women are more likely to work part-time and take advantage of flexible employment than men (Achatz, Fuchs, Kleinert, and Rossmann 2010).

External factors

In the following part of this paper, barriers will be discussed that are considered external or beyond women's control.

First of all, women are in the minority. There are fewer women in science, and, because of that, there are fewer women scientists who commercialise their knowledge. That is why women have to play by the rules created by men. It resembles the situation of tokens, as Rosabeth Kanter said in 1977. In her book, Men and Women of the Corporation, she addressed the issue of the relationship between men and women in a large U.S.-based corporation. Kanter says that the a woman-token does not need to work hard to be noticed but must try harder than men for her achievements to be noticed. Similarly in academic institutions where women are outnumbered by men. It is particularly perplexing in the so-called skewed groups where the male/female ratio is 85% to 15%. Women may then be treated first as representatives of their own category (i.e. women with all their intrinsic stereotypes), and their individual achievements are of secondary importance. Such an approach is corroborated in, for example, the theory of statistical discrimination (Ehrenberg and Smith 2000; Bielby and Baron 1986).

Another external barrier is the feminization of some fields of science (especially the humanities, social sciences, health care and education, as mentioned at the beginning of this paper). These scientific provinces attract more women than men, but are less prone to commercialisation. In the fields offering more commercialisation opportunities (biotechnology, mathematics, physics, chemistry) women are scarce. In other words, the distinguishing features of a scientific field make it more or less commercialisation-friendly, which directly translates into achievements in technology transfer from science to business.

Still, it must not be ignored that women have been historically under-represented in such positions in the faculty that naturally facilitate entrepreneurial activity (historical factors) (Xie and Shauman 1998). This barrier is closely related to another, namely the insufficient number of women in lead-

ership roles and positions (as ell as in the pipeline for such roles) where they could serve as role models and mentors (Moran 1992). Women absent from top research positions daunt other women who aspire to make it there, as they predict failure before they even try.

Besides the factors listed above, special attention should be paid to those that are attributable to the potential partners or institutions. First, there are certain attributes that venture capitalists may look for in scientists: high productivity, title and position. High productivity means the number and quality of published papers. It further means the number of citations, this indicator being less favourable for women. Another factor contributing to this gender gap is that venture capitalists are more comfortable collaborating with men than with women. Membership on scientific advisory boards is definitely male (Fox 2003; Murray and Graham 2005).

Another obstacle that is closely linked to the previous one is institutional affiliations. The issue is twofold. First, it is much easier to commercialise science when enjoying the backing of a prestigious institution. Admittedly, the greater the prestige it is accorded, the more frictionless commercialisation, and the scientist may expect a more generous support for this activity. It also promises a greater interest of potential business partners in cooperation. If, however, the indigenous institution is neither ranked among the world's leading research centres, nor respected among the domestic leaders, the marriage between science and business is even less likely. Certainly, it should be noted that the ideas for the commercialisation of scientific knowledge can be equally good regardless of where they are conceived (in a prestigious or less prestigious research centre). Yet, there are major differences in the manner of implementing such ideas in practice. Prestigious research institutions have developed and put in place adequate mechanisms supporting commercialisation, such as centres for technology transfer and incubators. They specialize in assisting researchers in establishing and running businesses capitalizing upon their scientific ideas. It seems that in this case the researcher's sex is less relevant.

However, having a closer look at these prestigious institutions, it transpires that the gender gap is still there among the employed scientists. It is more difficult for women than for men to take advantage of the prestige of an institution (Ding, Murray, and Stuart 2008).

Another obstacle in technology transfer is related to the fact that women lack the institutional support for patenting, as during the complicated procedures associated with obtaining a patent and securing the protection of intellectual property. Women receive less support and research attention from their universities, departments and their pursued discipline than their male colleagues. Perhaps universities and their technology licensing offices notice the high significance of female inventions, but this occurs after the fact when no initial support can be granted to commercialisation (Long and Fox 1995; Etzkowitz et al. 2000; Fox 2001; Long 2001).

As mentioned elsewhere, some scientific fields are more and some less commercialisation-friendly. While the social sciences and humanities are more challenging as far as commercialisation is concerned, technology and engineering are not (theoretically). But it does not follow that the commercialisation of knowledge is absent from the humanities or social sciences. An example of combining science and business in, as a matter of fact, any scientific domain is the membership in scientific advisory boards. Still, it has been demonstrated (Ding, Murray, and Stuart 2008) that also in this case no equal membership opportunities for men and women are guaranteed - such organisations reveal significant over-representation of men. Why is the membership in a scientific advisory board so important in terms of the commercialization of science? It is one of the selection criteria that businesses take into account when prospecting for partners. If women are denied access to such institutions, it may indirectly contribute to the rejection of their applications for other projects.

It needs to be added that this may also result in the reluctance of their supervisors to run the risk of promoting women or recommending them to handle the so-called stretch assignments. On the one hand, it is politically incorrect but, nevertheless, many people do it (Mattis and Allyn 1999).

The group of barriers discussed above is assumed to be independent from attitudes and initiatives undertaken by women. On the other hand, without a sufficient level of commitment and belief in their own capabilities, it can be even harder for women scientists to succeed in business. If the importance of male-female equality at any stage of a scientific career is firmly emphasized, the generations of women scientists to come will be able to commercialise science much more effectively and the leakages at different sections of the pipeline will become negligible.

Women scientists in business: a statistical overview

Research presented above show the disadvantage of women scientists. But, however, it is not compared with situation of men scientists. Relevant data are provided by Eurostat.

First of all, taking into account data for UE-27 one can see, that from 2003 the number of scientists working in R&D sector (Research & Development) is increasing. In 2009 it was over 3,6 mln of employees. If we take into account the

gender, women account for only 35%. In addition, the increase in the number of women each year is not as strong as men.

Analyzing data from 2009 we can estimate, how it looks like the participation of women in R&D sector in different countries. It turns out that the largest proportion of women in the sector takes place in Lithuania (54.7%), Latvia (53.7%) and Bulgaria (51.2%). And the lowest in the Netherlands (29.7%) and Luxembourg (28.4%). However, if we take into account data from outside Europe, it turns out that the rates in Asia are even lower. 18% for Japan, 21.5% for South Korea and 24% for China. There is lack of data for the USA. Based on these data we can conclude that women are relatively most strongly represented in the R&D sector in the former Eastern Bloc countries. In all these countries (except for the Czech Republic), the average share of women is higher than in the EU-27. These figures reflect the overall situation of women in science (She figures 2009) and show that in countries where rivalry and competition have a long tradition, in which the rules of the market economy are anchored from generations - women lose in comparison with male dominance in science.

However, in countries where scientists and businessmen remember the centrally planned economy, where other factors strongly influence the promotion opportunities and the possibility of combining science and business (often non-economic factors, especially those resulting from informal systems and connections) – the association with gender is not so strong.

Another issue is the very low participation of women in R&D sector in Asia. This is due to the culture of these countries (the most important factor), the strongly-rooted traditional family model and the place of women in the society (different from the western).

Discussion

The discussion above is not intended to demonstrate that women scientists fail to engage in the commercialisation of science as such. Indeed, they commercialise, but the type of commercialisation they elect does not overlap with men's choices. Women more often opt for soft activities (consulting), while men prevail in the spin-off initiatives (Klofsten and Jones-Evans 2000).

Consequently, the leaking pipeline metaphor can be applied to the commercialization of science in two ways. First, by regarding the commercialisation of scientific knowledge as one of the stages of a scientific career (usually one of the last), when the accumulated scientific knowledge can be put into business practice. Based on the presented analysis, a trend can be observed of a diminishing number of women in that last stage of a scientific career – the commercialisation of knowledge – due to the existing barriers. The statistics given at the beginning of this paper on women in science (the higher the scientific degree, the fewer women) prove this principle to be valid also for the stage of commercialisation. Second, the process of commercialisation of science is also varied. If all the forms of commercialization of knowledge are arranged in a sequence from the simplest like consultation to the most advanced like spin-offs, a specific pattern can be observed: at the beginning of the commercialization pipeline there are relatively many women, but when moving towards the other end there are more and more leakages, and actually very few women reach the ultimate form of commercialisation (Whittington and Smith-Doerr 2004).

The differences between men and women in the commercialisation of their scientific output reveal yet another aspect: the pay gap. The disparity in male and female pay has been exposed by many authors (Lips 2003; Montgomery and Powell 2003) and occurs labour market-wide. A similar situation takes place in science. Women scientists earn less than men, and the reasons for that are to be sought in, for example, uneven access to the process of commercialisation. For most researchers, technology transfer, besides offering greater career opportunities, is primarily expected to secure extra income. Barriers faced by women in the commercialisation of scientific knowledge deprive them of such an opportunity.

Conclusion

Barriers to the commercialization of scientific knowledge by women originate in at least two sources: women themselves and external factors beyond women's control. Bearing in mind the existing stereotypes about women, the reasons for so many women leaking from the pipeline are even more evident.

The analysis above demonstrated that there is a substantial gap between men and women at each stage of technology transfer and attempted entrepreneurial activity. This was examined by Thursby and Thursby (2005), Ding, Murray and Stuart (2006) etc.

To conclude, there is a need to further gender mainstreaming interventions and promote women academic entrepreneurs without disseminating gender stereotypes and without promoting the idea of the true academic entrepreneur being male only.

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