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Female Academic Entrepreneurship: Reviewing the Evidence and Identifying the Challenges

by

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Abstract

In this chapter the relative propensity for women academics to become entrepreneurs compared to male academics is explored. The overall evidence is that women constitute a very small proportion of academic entrepreneurs. For example, Rosser (2012) found that although in the US women are the dominant sex in small business start-ups, when it comes to the academic science, technology, engineering and mathematics (STEM) disciplines, women lag behind their male peers. Women file proportionately fewer invention disclosures and patents, launch fewer start-up companies, and are less successful in attracting venture capital and angel funding. A study by Colyvas et al. (2012) looked at the first step in the commercialisation process, (efforts to inventions) as well as the outcome of successfully transferring inventions to firms in academic medicine. While they found no gender differences they did show that women disclose fewer inventions than their male counterparts. This chapter, therefore, addresses the question: under what circumstances do women try and subsequently either fail or succeed in commercialising their research?

By way of theoretical underpinning, three strands of theory are applied: women as entrepreneurs, gender and the technology transfer process, and institutional analysis. Evidence from a number of studies is used to identify commercialisation patterns in the US and Europe. The chapter also examines measures adopted to support academic women's entrepreneurship and their effectiveness.

Introduction

The commercialization of academic science has come to be understood as economically desirable for institutions, individual researchers and the public (de Melo-Martin, 2013). In this chapter the relative propensity for women academics to commercialise their research by, for example, becoming entrepreneurs is explored. The overall evidence is that women — as in knowledge-based sectors generally (Arenius and Minniti, 2005, Micozzi et al., 2014) — comprise very few academic entrepreneurs, commercialising their research less frequently than their male counterparts.

For example, Rosser (2012) found that although in the US women are the dominant sex in small business start-ups, when it comes to the academic science, technology, engineering and mathematics (STEM) disciplines, women lag behind their male peers (see also Schiebinger, 2008). Women file proportionately fewer invention disclosures and patents, launch fewer start-up companies, and are less successful in attracting venture capital and angel funds. This pattern arguably represents an under-used resource for society because unexploited technology with the potential, for example, to bring about better healthcare is not developed and diffused. It is also a problem for universities, as new technologies can support expanded experimental learning for students as well as provide funding streams for researchers and their institutions (Howe et al., 2014).

This chapter addresses the question: under what circumstances do women try and, subsequently either fail or succeed in commercialising their research? Are these circumstances related to the women themselves, the external environment (Polkowska 2012), or other factors?

We perceive the context for our discussion to be twofold. Firstly, there is a general drive to commercialise university research. In the UK, for example, the Higher Education Business and Community Interaction Survey records information on Knowledge Exchange[1]. In North America the Association of University Technology Managers (AUTM)[2] collects similar data. Such monitoring highlights the significance attributed to commercialisation endeavours. Secondly, the relationship between career objectives, seniority and commericalisation is deemed important. Within this narrative are assumptions about the priorities given to commercialisation by women scientists, and whether, as Polkowska (2012) suggests, it represents the crowning achievement of a scientific career. In many countries, the association between seniority and commercialisation activity means that the actual number of women who might commercialise their research is small. There are also differences within STEM subjects (see, for example, Micozzi et al., 2014 on Italy). Moreover, gender plays a part in the choices women make in the form of commercialisation. It has been found that women opt for soft choices such as consultancy while men are more likely to form spin-off companies (Klofsten and Jones-Evans, 2000; Polkowska, 2012). Such tendencies are not, however, related to the quality of women's research but are more to do with the lesser rate at which their research is commercialised (Mitchell, 2011). There is also a measurement issue – i.e. what exactly is being measured and whether quality versus quantity is being accounted for (see Colyvas et al., 2011).

Reviewing patterns of commercialisation

Definitions

Commercialisation covers a variety of activities. Extant literature has mainly focused on the formation of academic spin-off companies, pre-commercialisation activity such as academic publishing, and patents and licensing. Other forms include consultancy, commercial research collaborations, as well as media contents e.g. educational videos and industrial scholarships.

Patenting performance is often linked to assessments of men's and women's publishing activity. These are taken as an indication of a scientist's research capabilities, and important determinants of career outcomes (Smith-Doerr, 2004; Whittington and Smith-Doerr, 2005). Many studies have found women to be less productive on this measure as they publish less often than male counterparts. However, Long (1992) found that although women publish less often, their publications had a

[1] <https://www.hesa.ac.uk/pr202> [accessed June 1 2015]
[2] <https://www.autm.net/Home.htm> [accessed June 1 2015]

greater impact than men's across career years and have consistently higher citations than those written by their male counterparts.

Studies to date also show that not all science disciplines can be equally commercialised to the same extent or in the same way – i.e. they do not affect men and women equally (Polkowska, 2012). While most commercialisation is in biotechnology, mathematics, physics and chemistry, there are differences in terms of gender balance. For example, there are more women in biology, but fewer in computer science. The context is a rise in the number of PhD candidates in female PhD students in the US, but a gender gap in pay and promotion. There has also been a gradual increase in the presence of women in science, technology and engineering. For example, in the US by 2010 women held half of all MD degrees and 52% of all PhDs in the life sciences (Ceci and Williams, 2011, as cited in de Melo-Martin, 2013). However, with regard to maths, statistics and physical sciences, women's share of doctorates was lower (Schintler and McNeeley, 2014).

The evidence

In this section we review the main findings from studies on female academic entrepreneurship and commercialisation. These are summarised in Table 1.

Entrepreneurship

The gendered nature of entrepreneurship is acknowledged in the literature (see, for example, Henry and Marlow, 2013; Jennings and Brush, 2012; Henry et al., 2015), with evidence of a general pattern that males are more likely to be entrepreneurs than females (GEM, 2012; 2013). While this also holds for academic entrepreneurs, the situation is more complicated. For example, Hewitt-Dundas (2015) found that female involvement in founding UKSPOs was high in comparison to levels of female representation on corporate boards and entrepreneurship levels. In their sample of UKSPOs, almost a third (31.1%) reported that a female had been involved in founding the company. This compares favourably to 20.4% of FTSE 100 companies with females on their corporate boards, and to 19% of small and medium sized enterprises in the UK with female CEOs or a management team having over 50% female representation. At the same time, females were significantly less likely to be the main founder in terms of the majority shareholding: accounting for 8.3% of all UKSPOs and, therefore, males were the most significant founder for 91.7% of UKSPOs.

Hewitt-Dundas (2015) found that two points were important to emphasise in terms of female involvement in founding UKSPOs. First, as the number of founders in a UKSPO increases, so too does the probability of a female being involved in the founding team. Second, where a female is the main founder, then the founding team tends to be smaller[3]. Where males are the main founder then the founding team has on average 3.0 members (sd=1.44) as compared to female-led UKSPOs where the founding team is comprised of 2.0 members (sd=1.02).

[3] Where males are the main founder then the founding team has on average 3.0 members (sd=1.44) as compared to female-led UKSPOs where the founding team is comprised of 2.0 members (sd=1.02).

Similarly, Micozzi et al. (2014) analysed a database of all academic spin-offs set up in Italy in 2002–2007. They found that females were the majority shareholders in less than 20% of Italian academic spin-offs. They also found that the number of female shareholders at start-up is higher when the majority shareholder is a female, and lower for firms with a higher average shareholder's share. This result extends to the number of female shareholders post-incubation. Firm size has a negative relationship with the number of females only at start-up and not in the post-incubation stage. They found weak evidence of a positive relationship between the share of the majority shareholder and number of female shareholders at start-up, when province, industry and year are not controlled for.

The number of female shareholders in the post-incubation period is strongly affected by the number of female shareholders at start-up, showing a degree of persistence in the number of female shareholders over time. Micozzi et al. (2014) also found that in spin-offs in which the number of female shareholders is particularly high, they all belong to service sectors, which in turn may be related to lower levels of capital invested at start-up (cf. Dautzenberg, 2012). This might also explain why academic spin-offs formed by females produce fewer patents or licences and/or are more failure prone than those formed by men.

Robb and Coleman (2010), consistent with Hewitt-Dundas (forthcoming), found that women-owned new technology-based firms were smaller and less likely to either generate growth or personal wealth for their founder. However, they were more likely to be satisfied with their firm's performance, be optimistic about its future and were less driven by economic measures of success than men. They rely more on external debt and less on equity than men, which may be associated with attitude towards growth. Dautzenberg (2012) found that female high tech entrepreneurs have smaller companies at start-up in terms of annual turnover and growth, and that technology start-ups tend to be in the service area.

Patenting and licensing

While it seems that women yield fewer patents than their male counterparts, the quality and impact of women's patents is either equal or superior to those of male scientists. Furthermore, women produce less commercial work than their male counterparts. Colyvas et al. (2012) examined the period 1991 to 1998 when patenting had become more prevalent in academic medicine. They captured the first step in the commercialisation process (efforts to inventions), as well as subsequent successful licensing of faculty inventions to a company using invention disclosures and licenses (an estimate of transfer to firms). Thus, they were able to compare behaviour in engaging in commercialisation to that of outcomes of engagement. While they found no gender differences in outcomes, they did find that women disclosed fewer inventions than their male counterparts. However, women's inventions were just as likely to secure licenses to firms as those of men. This suggests that women could be an untapped resource of entrepreneurial talent in academia.

In their study, Link et al. (2007) used a Research Value Mapping Program (Georgia Tech) Survey of Academic Researchers. Survey data were collected from a sample of university scientists and engineers with a PhD at the 150 Carnegie Extensive Doctoral/Research Universities during the time period spring 2004 to spring 2005.

The sample was proportional to the numbers of academic researchers in the various fields of science and engineering, and balanced between randomly selected men and women. They found that Probit estimates reveal that male faculty members are more likely than female faculty members to engage in informal commercial knowledge transfer and consulting. Overall, very few academics engage in licensing (Thursby and Thursby, 2005). Their findings also revealed that only 2 in 10 academics in 11 US research universities disclosed or had disclosed once in 17 years. There was some increase over time but only in a minority of faculty over a 17-year period 1983 to 1999.

De Melo-Martin (2013) argues that commercial activity, particularly that resulting from patenting, appears to be producing changes in the standards used to evaluate scientists' performance and contributions. In this context, concerns about a gender gap in patenting activity have arisen, and some have argued for the need to encourage women to seek more patents. They argue that because academic advancement is mainly dependent on productivity (Stuart and Ding, 2006; Azoulay et al., 2007), differences in research output have the power to negatively impact women's careers.

Nevertheless, calls to encourage women to patent on grounds that such activity is likely to play a significant role in the betterment of both women's careers and society seem to be based on two problematic assumptions: (1) that the methods to determine women's productivity in patenting activities are an appropriate way to measure their research efforts and the impact of their work, and (2) that patenting, particularly in academia, benefits society. However, patents as an indicator of the respective value of men and women's measure of productivity have at least two problems. The first is that not all patents are of a similar quality and importance, for example, through commercial impact and technological influence (Whittington et al., 2005). The second is that propensity to patent varies by sector. Colyvas et al. (2012) also caution against the use of patent data as an empirical measure of innovation. For example, sample limits impact the ability to capture institutional differences; faculty entry and exit rates would address selection effects. Furthermore, commercial efforts might be conditioned by teaching loads and forms of research support. Finally, patent data only reflect one form of technology transfer, especially in the life sciences.

Based on data covering two decades of life science PhD cohorts it was found that women yield fewer patents than male counterparts, but that the quality and impact of womens' patents was equal or superior to those of male scientists. De Melo-Martin (2013, p. 495) argues that, on the basis of the evidence in relation to the quality of women's academic outputs and citations, 'there is no evidence that women do less important work than men'. However, women generally produce less commercial work than men throughout their careers (Whittington and Smith-Doerr, 2005).

By comparison, in the biotech sector, female inventors were patenting less than men (McMillan, 2009). However, the nature of the underlying science (type, funding sources, and author institutions) cited in their patents was both different and superior in many respects to that of men. Moreover, women's patents were valued more highly than those of men and of joint work between men and women. McMillan (2009) concluded that by coupling the findings for the category 'both' on the age of patents (most recent) and the number of inventors (both), there is a life cycle that can be deduced by these findings. This is that biology research efforts were moving from men collaborating only with men, and women with other women, to more joint work. In 2008, however, women's overall role in producing commercial outcomes from high-quality work remained modest. Therefore, companies should make sure that more women work towards acquiring a patent. In this regard, Whittington and Smith-Doerr (2005) suggest that female life scientists must overcome two kinds of gender disparity in commercial activity: both in involvement (in their decisions and opportunity to patent), and in productivity.

In Thursby and Thursby (2005) women were only 8.55% of their sample of US Science and Engineering Faculty at 11 major US research institutions, were mostly in biological sciences, and tended to be younger. However, they found that women were less likely to disclose inventions than men in spite of no significant differences in publication patterns. Disclosure patterns converged over time but a gap remained.

Explanations and effectiveness

Women as entrepreneurs

Explanations for gender differences in business start-ups include context (country, sector, etc), human capital, entrepreneurial intention and motivation, and gender and entrepreneurial networks (Hanson and Blake, 2009; Etkzowitz et al., 2000). Overall, regardless of country, men are more likely to be involved in entrepreneurial activity than women at all stages, from early stage through to established businesses. National and regional differences are shown to be important. For example, in the US the majority of small businesses are started by women (Howe et al., 2014). Overall, the number of women entrepreneurs per se is increasing in the UK and elsewhere (Mayer, 2008). It is, however, greatest in the highest income countries regardless of activity (Ranga and Etzkowitz, 2010). Significantly, women's commercialisation activities are found to be greater in industry than in academia (Whittington and Smith-Doerr, 2004).

In the US, women tend to own businesses in those high-tech sectors where women are disproportionately represented in locations such as Boston and Silicon Valley (Mayer, 2008). Furthermore, Mayer found significant differences in sectoral and spatial segmentation in high-tech economies such as Boston; this was regardless of age. This effect was not significant at the regional level, but inter-metropolitan differences in high tech economies for such female-typed high tech firms but they were generally not located in core high-tech areas. However, those that did locate in high-tech areas tended to be larger (in terms of both employment and sales) than those in the more peripheral areas. Mayer (2008) also suggested that feminist theories relating to labour market segmentation and the concept of female entrapment (i.e. trapped in female type sectors) help explain a possible 'glass ceiling' whereby male stereotypes prevent women from acquiring management skills and positions that might equip them for starting and running a business.

Regional context has several different but associated dimensions. For example, networks are embedded in place-based social economic, cultural and political structures (Hanson and Blake, 2009). Explanations relate to different status positions that are inherent in gender relations, reflecting inequality of opportunity, for example, in access to business development resources such as venture capital (Mayer, 2008).

Table 1:

Indicator	General patterns	Location	Authors
Spin-offs	Gender gap is significant but spatially heterogeneous – possibly reflecting cultural and environmental differences between Italian provinces (more in the North and Central regions); a disadvantage to females at the start-up funding stage which reduces their chances of success, and forces them into the service sector. Social relationships between females may compensate and reduce barriers to entrepreneurship.	Italy	Micozzi et al., 2014.
	Female students are less likely to start their own businesses than males. Significant gender differences in perceived feasibility and desirability. Females are less confident, more tense, reluctant and concerned about entrepreneurship but fewer differences exist in entrepreneurial intention. Mentoring and tutoring structures rated as more important by females than males.	10+ countries	Dabic et al., 2012.
	Incubators.	Sweden	Lindholm Dahlstrand and Politis.
Patents	Women yield fewer patents than male counterparts.	US	Whittington and Smith-Doerr, 2004; Murray and Graham, 2007.
	Quality and impact of women's patents is equal or superior to those of male scientists.	US	Bunker Whittington and Smith-Doerr, 2005; Ding et al., 2006; Stephan and El-Ganainy, 2007; McMillan, 2009.
	Women produce less commercial work than male counterparts.	US	
Disclosure of inventions (licensing)	Women are less likely to disclose invention than men although no significant differences in publications.	US	Thursby and Thursby, 2005.
		US	Colyvas et al., 2012.

Mayer suggests that more research is needed on how they are embedded in broader cultural discourses and structures, and how this affects potential agency for change. It relates to access to engagement with different networks.

Human capital arguments suggest that levels of entrepreneurial activity are associated with education. High levels of formal education are associated with a propensity for entrepreneurship (Reynolds et al., 2001). However, Unger et al. (2011), and Marvel et al. (2014) suggest that the relationship is more complex than this. Marvel et al. (2013) argue that an individual can invest in education and experience, and one's outputs depend partly on the rate of return on the human capital one possesses. Specific human capital refers to skills or knowledge that is useful to a particular setting or industry. Similarly Unger et al. (2011) suggest that human capital is most important if it is task-related and consists of outcomes of human capital investments rather than human capital investments themselves. It should be understood as processes of learning, knowledge acquisition and the transfer of knowledge to entrepreneurial tasks. In this context, it is not the level of education that matters - as it is a given that women academics have high levels of human capital – rather, it is the skills and knowledge required for entrepreneurship and commercialisation that matter, and these are often lacking in women (Ahl, 2006). This is necessarily interdependent with entrepreneurial motivation and intention.

Entrepreneurial motivation and intention have been found to be gendered (Micozzi et al., 2014). While entrepreneurs share a common desire for independence and control over their future, women entrepreneurs specifically often seek to break through the glass ceiling. Dabic et al. (2014) cited Shapero's (1982) entrepreneurial event and Ajzen's (1991) theory of planned behaviour models to illustrate these points. Shapero argues that entrepreneurial intentions are directly shaped by perceived feasibility and perceived desirability of entrepreneurial activity and propensity to act. Ajazen's theory claims that attitude towards the act (or personal attraction - Linan and Santos, 2007), social norms (or perceived behavioural control) or self sufficiency (Linan and Santos, 2007) influence entrepreneurial intention. Moreover, Arenius and Minniti (2005) find self-reported confidence in having the relevant skills for running a business to affect the propensity to be an entrepreneur (see also Ahl, 2006; Brighetti and Lucarelli, 2015). They also find that women describe themselves as risk averse, a sex-based stereotype, but evidence from Italy suggests that in practice there is no difference in attitudes towards risk.

Both motivation and intention might be related to the finding that women entrepreneurs are sometimes seen as second order entrepreneurs: first order are implicitly male (Faltholm et al., 2010). There is, therefore, a substantial risk that interventions aimed at supporting women entrepreneurs instead of promoting structural changes reinforce the image of the successful male entrepreneur. It is also suggested that women possibly approach entrepreneurship as a secondary or a temporary activity when compared to men who approach an entrepreneurial career with an entrepreneurial spirit (Achtaz et al., 2009).

Moreover, low levels of female entrepreneurship - associated with the realistic expectation that banks, venture capitalists and business angels are less likely to support female initiated enterprises – may explain the tendency to wait until a higher level of resources has been acquired rather than a reluctance to take risks (Ranga and

Etzkowitz, 2010). The portrayal of entrepreneurship in academia as a male activity may result in excluding women. Thus, ways of promoting women academic entrepreneurs without reproducing gender stereotypes are needed. This requires gender mainstreaming interventions (Faltholm et al., 2010).

Context also matters in other respects, in that household/family context might have the largest impact on female entrepreneurship even where women have the same motivation (Jennings and McDougald, 2007; Micozzi et al., 2014). As with other entrepreneurs, female students are also less likely than males to start a business. Dabic et al. (2012) found significant gender differences in perceived feasibility and desirability of entrepreneurship among students in 10 European countries. Females are less confident, more tense, reluctant and concerned about entrepreneurship, but fewer differences were found to exist in entrepreneurial intention. Mentoring and tutoring structures to assist in developing entrepreneurial skills were rated as more important by females than males. However, realistic practical barriers exist. A reluctance to undertake the commercialisation of research in academia has been associated with the challenge of being a lecturer, researcher, leader and an entrepreneur at the same time (Faltholm et al., 2010).

Gender and the technology transfer process

The process of commercialisation has been explained as a social process, for example in networking and human capital (see, for example, Polkowska, 2012). Women have been found to have less access to important networks and R&D, which affect the likelihood of commercialising their research. Both affect an academic's position in relation to external funding and being published, i.e. key precursors to entrepreneurial activity. This has been explained in relation to opportunity recognition as social networks and prior work/life experiences influencing the process of opportunity recognition (DeTienne and Chandler, 2007; Micozzi et al., 2014).

Men typically have larger social networks and more extensive previous work/life? experience than women, as well as different types of networks. This is particularly important when raising finance. Networks have been shown to be important in the university context in the broader technology transfer process. For example, Ding et al. (2006) found that females were less likely to know people who could firstly help them recognise the commercial potential of their research, and secondly, help them commercialise it effectively.

Furthermore, females are more likely to obtain start-up funds through strong tie networks (family and friends), and obtain less than men, which again ties them into starting businesses with lower capital intensity (see also Dautzenberg, 2012). Friendship in the research world is gender-based, and women have a lower capacity for associating with colleagues who are patenting, commercialising or have contacts with industry (Murray and Graham, 2006).

Networks are also important in the formation of scientific advisory boards (which are usually male; see, for example, Murray and Graham, 2007), and in access to venture capitalists. Women are therefore possibly excluded from academic entrepreneurial networks (Faltholm et al., 2010; Stephan et al., 2007). Scientific advisory board membership is one of the selection criteria that businesses take account of when prospecting for partners (Polkowska, 2012). This raises the question of whether women are less successful in selling research results to others, or selected for honours, or are not invited to participate in start-up activity (Babcock and Laschevr, 2003; Murray and Graham, 2007).

Institutional analysis

Within the domain of social sciences, institutional analysis examines how institutions - i.e., structures and mechanisms of social order and cooperation governing the behavior of individuals - behave and function according to both empirical rules (informal rules-in-use and norms) and also theoretical rules (formal rules and law). It concerns how individuals and groups construct institutions, how institutions function in practice, and the effects of institutions on individuals, societies and the community at large. Institutional analysis helps identify constraints within an organization that might undermine policy implementation. Such constraints may exist at the level of internal processes, relationships among organizations, or they may be system-wide. Institutional analysis evaluates formal institutions, such as rules, resource allocation, and authorization procedures, as well as "soft" institutions, such as informal rules of the game, power relations and incentive structures that underlie current practices. In the latter sense, institutional analysis identifies organisational stakeholders that are likely to support or obstruct a given reform[4].

Studies have identified that women lack institutional support for patenting (Etkowitz et al., 2000; Fox 2001; Long, 2001). Smith-Doerr (2004), for example, found that women are more likely to patent in more flexible network-based organisational structures than in hierarchical organisations in academia and industry (Whittington and Smith-Doerr 2004). Moreover, discipline as an institutional factor is important. For example, Morgan et al. (2001) finds that women in the US who patent are five times more likely to be life scientists than engineers. In industry, however, a third of women patent, a higher rate than for female life scientists. Overall, however, women found most career advantages in entrepreneurial science-based firms (Smith-Doerr, 2004).

Recent research (e.g., Corley and Gaughan, 2005) suggests that gender findings may be attenuated by the institutional setting. Link et al. (2007) found that women who are affiliated with interdisciplinary university research centres have commercial activity profiles that more closely resemble male centre affiliates than females affiliated only with traditional academic departments. They also found that tenured faculty members and those who are actively involved in research grants are more likely to engage in informal technology transfer than non-tenured faculty members.

In patenting, commercial involvement may also be a new fault-line: between those who patent and those who do not. Owen-Smith and Powell (2001) argue that an understanding of gender inequality in commercial activity requires a conceptualisation of the multiple ways in which men and women may be involved and whether a commercial 'pipeline' of involvement is present for women in science. Thus, Whittington and Smith-Doerr (2005) suggest that female life scientists must overcome

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[4] <http://siteresources.worldbank.org/INTPSIA/Resources/490023-1121114603600/12996_workshop_instanalysis.pdf> [accessed April 8 2015]

two kinds of gender disparity in commercial activity – both in involvement and their decisions and opportunity to patent - and in productivity. They note that in the US at least, scientists have to make decisions about the level of involvement they will have in commercial work. Those who are involved are institutional and personally rewarded: increases in research funding, access to better equipment, personal wealth, and the UK status in the Research Excellence Framework in which 'Impact' such as through patenting in STEM subjects is assessed[5].

The policy implication of all this is that universities would benefit from devoting resources to enable women scientists to commercialise (Whittington and Doerr-Smith, 2005). However, de Melo-Martin (2013) argues that encouraging women to patent more may harm their careers. Rather, it would be better to be clear about the goals of such activity and assess the overall impact rather than counting the number of patents. She also challenges the notion that patents per se are of value to society, as they increase secrecy and may delay access to new knowledge; she also highlights other limitations about the assumptions relating to the value of patents.

Colyvas et al. (2012) found that gender differences in commercialising research in three US medical schools are highly conditioned by the employment context and resources. In their study, gender differences are attributed to the use of outcome measures that capture both behaviour and performance.

Howe et al. (2014) found that developing solutions to low levels of women academic entrepreneurs at Ohio State University in the form of a curriculum for an entrepreneurship workshop series was problematic. This was due to cultural differences in what women would need to know to become motivated to become engaged in commercialisation. This is when activity is framed in terms of societal impact.

In practice this required getting women to envision themselves as entrepreneurs, with activities and learning tailored to their own work. This meant one-to-one analysis of research potential of the market place. This also meant that women needed to learn the landscape – that forming a start-up was not the only way forward; to realise that commercialisation partners will take on tasks that women would prefer not to do; and identifying resources. The NSF funded REACH programme has supported nearly 100 women (faculty and post-docs) at nearly 15 institutions. Post-docs were keen as were individuals who had experience in commercialisation. Cultivating a community of women entrepreneurs is essential: women have different experiences to men, hence sharing experiences is beneficial. Networks expand one's circle of colleagues. Similarly Nilssson (2015) argued that attracting more women to engineering would occur if the content was made more socially meaningful by reframing the goals of the engineering research and curriculum to be more relevant to societal needs. Moreover, in the US universities' commercialisation is not part of the reward structure. Therefore, explicit value must be placeed on entrepreneurialism for promotion and tenure, annual salary reviews and contributing to career development.

Other institutional measures to promote entrepreneurship include incubators. In their study, Lindholm Dahlstrad and Politis (2009) focused on university incubators for

[5] <http://www.ref.ac.uk/> [accessed April 8 2015]

women's academic entrepreneurship and examined the significance of university incubators for the promotion and development of women's academic business start-ups. They concluded that the Swedish incubators in their study do not show any evidence of being able to decrease the gender gap in the commercialization of university science.

Conclusions

This chapter explored the relative propensity for women academics to become entrepreneurs as compared to their male counterparts. Drawing on relevant and contemporary scholarship, as well as extant reports, in the areas of entrepreneurship and gender, patenting and licensing, technology transfer and institutional analysis, our research question sought to uncover the particular circumstances under which women attempt to commercialise their research. In addressing this question, we also examined some of the measures currently adopted in the EU to support academic women's entrepreneurship.

In quantitative terms, the evidence reveals significantly less commercialisation activity among female academics than among male academics. However, the quality of women's commercialisation activity appears to be superior to men's, suggesting that counting alone does not offer a full and accurate picture.

The evidence we reviewed also suggests that the explanations for women's lower commercialisation levels are multi-faceted. Notwithstanding the many definitional issues associated with commercialising academic research, and the fact that not all science disciplines may be commercialised to the same extent, academic publishing activity was found to have a positive impact on women's careers as it is seen as an indication of esteem. The level of patenting and licensing; access to networks and venture capital; propensity toward and involvement in entrepreneurship; and the specific and typically limited institutional support environment were all highlighted as other key influencing factors impacting the level of commercialisation amongst women. In parallel to general entrepreneurial activity, it is clear from our review that women academics seeking to commercialise their research do experience different and often more complex challenges than their male counterparts.

Given the above, the evidence shows that women academics attempt to commercialise their research under extremely challenging conditions, many of which relate to inherent gender biases in the academic system, the majority of which reflect trends in entrepreneurship globally. In light of this, the question then becomes: what, if anything, can be done to change the situation so as to increase women's level of commercialisation activity? Finding appropriate solutions by way of addressing this question, however, can be problematic, with some commentators observing that solutions can often make things worse (Melo-Martin, 2013). Practical suggestions offered to date include providing executive coaching and network coaching to overcome gender stereotypes (Brighetti and Lucarelli, 2015). Incubation facilities seem a logical approach to establishing a commercialisation-friendly environment, but evidence to date shows them to have little or no impact on decreasing the gender gap in the commercialization of university science (Lindholm Dahlstrad and Politis, 2009). We conclude that universities would be best served investing efforts in two main areas: firstly, developing women's confidence levels and increasing their self-efficacy with regard to their commercialisation abilities. Secondly, consistent with Colyvas et al. (2012), improving academic researchers' employment context and resources so that they account for gender differences. After all, women need to be able to first see themselves as valued employees, commercial actors and potentially entrepreneurs before they can expect others to see them as such (Howe et al., 2014).

Avenues for future research

Given that the commercialisation process is both lengthy and complicated, varies from discipline to discipline, and is also affected by the particular environment in which the academic researcher resides, future studies would benefit from adopting both longitudinal and comparative research designs. Such studies could explore the impact of different academic support environments, examine reward structures in specific institutions and in particular countries, account for the gender balance in academic research staff cohorts and consider the impact on career trajectories. Further work is also required to evidence the effectiveness of existing support measures, especially those that claim to specifically encourage women academics' commercialisation activity. It would be especially interesting to note whether scientific disciplines that were traditionally male-dominated and are now experiencing a considerable gender shift toward the predominately female – for example, human and veterinary medicine - offer new insights for the study of women academics' commercialisation activity. Studies of this nature could not only contribute to theory, but could also yield considerable practical value in terms of appropriate support mechanisms to fully develop women's commercialisation potential.

References

Achatz, J., M. Beblo and E. Wolf, 'Berufliche Segregation', in *Geschlechterungleichheiten im Betrieb. Arbeit, Entlohnung und Gleichstellung in der Privatwirtschaft*, ed. by Projektgruppe GiB (Berlin, 2009) pp. 89–139

Ahl, H., 'Why Research on Women Entrepreneurs Needs New Directions', *Entrepreneurship Theory and Practice*, 30.5 (2006), 595–621

Arenius, P., and M. Minniti, 'Perceptual Variables and Nascent Entrepreneurship', *Small Business Economics*, 24.3 (2005), 233–47

Azjen, I., 'The Theory of Planned Behavior', *Organizational Behavior and Human Decision Processes*, 50 (1991), 179–211

Azoulay, P., W. Ding, and T. Stuart, 'The Impact of Academic Patenting on the Rate, Quality, and Direction of (Public) Research Output'. *The Journal of Industrial Economics*, 57.4 (2009), 637–76

Babcock, L., and S. Laschevr, *Women Don't Ask* (Princeton: Princeton University Press, 2003)

Bozeman, B., J. Dietz, and M. Gaughan, 'Models of Scientific Careers: Using Network Theory to Explain Transmission of Scientific and Technical Human Capital', *International Journal of Technology Management*, 22.7 (2001), 716–40

Brighetti, G., and C. Lucarelli, ‘Gender Differences in Attitudes Towards Risk and Ambiguity: When Psycho-Physiological Measurements Contradict Sex-Based Stereotypes’, *International Journal of Entrepreneurship and Small Business*, 24.1 (2015), 62–82

Brockhaus, R. H., ‘Risk Taking Propensity of Entrepreneurs’, *Journal of Academic Management*, 23.3 (1980), 509–20

Ceci, S. J., and W. M. Williams, ‘Understanding Current Causes of Women's Underrepresentation in Science’, *Proceedings of National Academy of Science of the United States*, 22 (2011), 8 <http://www.pnas.org/content/108/8/3157.full> [accessed June 1 2015]

Colyvas, J. A., K. Snellman, J. Bercovitz, and M. Feldman, ‘Disentangling Effort and Performance: a Renewed Look at Gender Differences in Commercialising Medical School Research’, *Journal of Technology Transfer*, (2012) 1–12

Corley, E., and M. Gaughan, ‘Scientists’ Participation in University Research Centres: What are the Gender Differences?’, *Journal of Technology Transfer*, 30.4 (2004), 371–81

Dabic, M., T. Daim, E. Bayraktaroglu, I. Novak, and M. Basic, ‘Exploring Gender Differences in Attitudes of University Students Towards Entrepreneurship: An International Survey’, *International Journal of Gender and Entrepreneurship*, 4.3 (2012), 316–36

Delmar, F., P. Davidsson, and W. B. Gartner, ‘Arriving at the High-Growth Firm’, *Journal of Business Venturing*, 18.2 (2003), 189–216

Dautzenberg, K., ‘Gender Differences of Business Owners in Technology-Based Firms’, *International Journal of Gender and Entrepreneurship*, 4.1 (2012), 79–98

De Melo-Martín, I., ‘Patenting and the Gender Gap: Should Women Be Encouraged to Patent More?’, *Science and Engineering Ethics*, 19.2 (2013), 491–504

DeTienne, D. R., and G. N. Chandler, ‘The Role of Gender in Opportunity Identification’, *Entrepreneurship Theory and Practice*, 31.3 (2007), 365–86

Ding, W. W., F. Murray, and T. Stuart, ‘Gender Differences in Patenting in the Academic Life Sciences’, *Science*, 313 (2006), 665–67

Etkowitz H., C. Kemelgor, B. Uzzi, *Athena Unbound: The Advancement of Women in Science and Technology* (Cambridge: Cambridge University Press, 2000)

Fältholm, I., L. Abrahamsson, and E. Källhammer, ‘Academic Entrepreneurship – Gendered Discourses and Ghettos’, *Journal of Technology Management and Innovation*, 5.1 (2010), 5–163

Fox, M. F., ‘Women, Science and Academia: Graduate Education and Careers’, *Gender and Society*, 15.5 (2001), 654–66

GEM Women’s Report, (2012) <http://www.babson.edu/Academics/centers/blank-center/global-research/gem/Documents/GEM%202012%20Womens%20Report.pdf> [accessed June 1 2015]

Hanson, S., and M. Blake, ‘Gender and Entrepreneurial Networks’, *Regional Studies*, 43.1 (2009), 135–49

Henry, C., and S. Marlow, ‘Exploring the Intersection of Gender, Feminism and Entrepreneurship’, in the *Handbook of Research in Entrepreneurship*, ed. by Alain Fayolle (Cheltenham: Elgar, forthcoming)

Henry, C., L. Foss, and H. Ahl, ‘Gender and Entrepreneurship Research: A Review of Methodological Approaches’, *International Small Business Journal*, (2015)

Hewitt-Dundas, N., ‘UK University Spin-Outs’, *ERC Research Paper No.35*, mimeo Queens University Belfast (2015)

Howe, S. A., M. C. Juhas, and J. M. Herbers, ‘Academic Women: Overlooked Entrepreneurs’, *Peer Review*, 16.2 (2014) <https://www.aacu.org/peerreview/2014/spring/howe> [accessed January 29 2015]

Hunter, L. A., and E. Leahey, ‘Parenting and Research Productivity: New Evidence and Methods’, *Social Studies of Science*, 40.3 (2010), 433–51

Klofsten, M., and D. Jones-Evans, ‘Comparing Academic Entrepreneurship in Europe – The Case of Sweden and Ireland’, *Small Business Economics*, 14 (2000), 299–309

Jennings, J. E., and M. S. McDougald, ‘Work-Family Interface Experiences and Coping Strategies: Implications for Entrepreneurship Research and Practice’, *Academy of Management Review*, 32.3 (2007), 747–60

Laznjak, J., and others, ‘Women in Science Commercialization: Looking for Gender Differences’, *Gender, Technology and Development*, 15 (2011), 175–200

Leahey, E., ‘Gender Differences in Productivity: Research Specialization as a Missing Link’, *Gender & Society*, 20.6 (2006), 754–80

Lindholm Dahstrand, A., and D. Politis, ‘Women Business Ventures in Swedish University Incubators’, *International Journal of Gender and Entrepreneurship*, 5.1 (2013), 78–96

Linan, F., and F. J. Santos, ‘Does Social Capital Affect Entrepreneurial Intentions?’, *International Advances in Economic Research*, 13.4 (2007), 443–53

Link, A. N., D. S. Siegel, and B. Bozeman, ‘An Empirical Analysis of the Propensity of Academics to Engage in Informal Technology Transfer’, *Industrial and Corporate Change*, 16.4 (2007), 641–55

Long, S., *From Scarcity to Visibility: Gender Differences in the Careers of Doctoral Scientists and Engineers* (Washington, D.C: National Academy Press, 1992)

McMillan, G. S., 'Gender Differences in Patenting Activity: An Examination of the US Biotechnology Industry', *Scienometrics*, (2009) DOI: <10.1007/s11192-008-2101-0>

Marvel, M. R., 'Human Capital and Search-Based Discovery: A Study of High-Tech Entrepreneurship', *Entrepreneurship: Theory & Practice*, 37.2 (2013), 403–19

Mayer, H., 'Segmentation and Segregation Patterns of Women-Owned High-Tech Firms in Four Metropolitan Regions in the United States', *Regional Studies*, 42.10 (2008), 1–27

Micozzi, A., F. Micozzi, and P. Pattitoni, 'Fostering Female Entrepreneurship in Academic Spin-Offs', in *University Evolution, Entrepreneurial Activity and Regional.Competitiveness*, ed. by David Audretsch and others (London: Springer, 2014), pp. 49–70

Morgan, R. P., C. Kruytbosch, and N. Kannankutty, 'Patenting and Invention Activity of U.S. Scientists and Engineers in the Academic Sector: Comparisons with Industry', *Journal of Technology Transfer*, 26 (2001), 173–83

Murray, F., and L. Graham, 'Buying Science and Selling Science: Gender Differences in the Market for Commercial Science', *Industrial and Corporate Change*, 16 (2007), 657–89

Owen-Smith, J., and W. W. Powell, 'To Patent or Not: Faculty Decisions and Institutional Success at Technology Transfer', *Journal of Technology Transfer*, 26.1 (2001), 99–114

Polkowska, D., 'Women Scientists in the Leaking Pipeline: Barriers to the Commercialisation of Scientific Knowledge by Women', *Journal of Technology Management and Innovation*, 8.2 (2013), 156–65

Ranga, M., and H. Etzkowitz, 'Athena in the World of Techne: The Gender Dimension of Technology, Innovation and Entrepreneurship', *Journal of Technology Management and Innovation*, 5.1 (2010), 1–12

Robb, A., and S. Coleman, 'Financing Strategies of New Technology-Based Firms: A Comparison by Gender', *Journal of Technology Management & Innovation*, 5.1 (2010), 30–50

Rosser, S. V., *Breaking into the Lab: Engineering Progress for Women in Science* (New York: New York University Press, 2012)

Schiebinger, L. L., *Gendered Innovations in Science and Engineering* (Stanford: Stanford University Press, 2008)

Schintler, L. A., and C. McNeeley, ‘Gendered Science in the 21st Century: Productivity Puzzle 2.0?’ (2014) <http://genderandset.open.ac.uk/index.php/genderandset/article/view/219/389> [accessed June 1 2015]

Shapero A., and L. Sokol, ‘Social Dimensions of Entrepreneurship’, in *The Encyclopedia of Entrepreneurship*, ed. by C. Kent, D. Sexton, K. Vesper (Prentice-Hall: Englewood Cliffs, 1982), pp. 72–90

Smith-Doer, L., *Women's Work: Gender Equality vs. Hierarchy in the Life Sciences* (London: Lynne Rienner Publishers, 2004)

Stuart, T., and W. Ding, ‘When do Scientists Become Entrepreneurs? The Social Structural Antecedents of Commercial Activity in the Academic Life Sciences’, *American Journal of Sociology*, 112.1 (2006), 97–144

Stephan, P. E., and A. A. El Ganainy, ‘The Entrepreneurial Puzzle: Explaining the Gender Gap’, *Andrew Young School of Policy Studies Research Paper Series*, No. 07–09 (2007)

Stephan, P., G. Black, and T. Chaing, ‘The Small Size of the Small Scale Market: The Early-Stage Labor Market for Highly Skilled Nanotechnology Workers’, *Research Policy*, 36.6 (2007), 887–92

Thursby, J. G., and M. C. Thursby, ‘Gender Patterns of Research and Licensing Activity of Science and Engineering Faculty’, *Journal of Technology Transfer*, 30 (2005), 343–53

Unger J. M., A. Rauch, M. Frese, and N. Rosenbusch, ‘Human Capital and Entrepreneurial Success: A Meta-Analytical Review’, *Journal of Business Venturing*, 26 (2011), 341–58

Whittington, K. B., and L. Smith-Doerr, ‘Gender and Commercial Science: Women’s Patenting in the Life Sciences’, *Journal of Technology Transfer*, 30 (2005), 355–70

Whittington, K. B., and L. Smith-Doerr, ‘Women Inventors in Context Disparities in Patenting across Academia and Industry’, *Gender & Society*, 22.2 (2008), 194–218