Female Academic Entrepreneurship and Commercialisation: Reviewing the evidence and identifying the challenges

Lawton Smith, H, Etzkowitz, H Meschitti, V and Poulovassilis, A (2017) 'Female Academic Entrepreneurship and Commercialisation: Reviewing the evidence and identifying the challenges' in The Routledge Companion to Global Female Entrepreneurship C.Henry, T. Nelson and K Lewis (eds) London:Routledge 78-92

Abstract

This chapter considers the propensity for women academics to become entrepreneurs and to commercialise their research in comparison to male academics. A review of the academic literature and published reports suggests that women constitute a very small proportion of academic entrepreneurs; this is especially the case in science, technology, engineering and mathematics (STEM) disciplines. Women in STEM disciplines have been shown to file proportionately fewer invention disclosures and patents, launch fewer start-up companies, and are less successful in attracting venture capital and angel funding than their male counterparts. This chapter 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. The chapter draws on a number of studies to identify commercialisation patterns in the US and Europe.

Introduction

The commercialization of academic science is acknowledged as economically desirable for institutions, individual researchers and the public (de Melo-Martin, 2013). In this chapter the relative propensity for women in academic science, technology, engineering and mathematics (STEM) disciplines, to commercialise their research by, for example, becoming entrepreneurs and patenting, is explored through a review of the available academic literature and published reports. The overall evidence suggests that women — as in knowledge-based sectors generally (Arenius and Minniti, 2005, Micozzi et al., 2014) — comprise very few academic entrepreneurs [1] and commercialise their research less frequently than their male counterparts.

Rosser (2012) found that although in the US women are the dominant sex in small business start-ups, they lag behind their male peers in the STEM disciplines (see also Schiebinger, 2008). Women file proportionately fewer invention disclosures and patents, launch fewer start-up companies, and are less successful in attracting venture

[1] Academic entrepreneurs are members of the academic staff of universities who choose to set up their own businesses. They may or may not continue to work in the university after setting up a company.

capital and angel funds than their male counterparts. This pattern arguably represents an under-used resource because unexploited technology with the potential to benefit society 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 academics try and, subsequently either fail or succeed in commercialising their research? Additional questions, such as - are these circumstances related to the women themselves, the external environment (Polkowska 2012) or to other factors - are also explored. 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. 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 commercialisation is deemed important. Within this narrative are assumptions about the priorities given to commercialisation by women scientists, and whether, as Polkowska (2012) suggests, such assumptions represent 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 with regard to the Italian context). 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

General patterns

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

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

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 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. However, women still lag behind men 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 medical (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 main findings from extant literature on female academic entrepreneurship and commercialisation (patents and disclosure of inventions (licensing) are summarised in Table 1. These highlight a gender gap between men and women in quantity of activity but also more positive findings relating to the quality of women's commercialisation activity.

Insert Table 1 about here

Entrepreneurship

The underlying context to patterns of female academic entrepreneurship in STEM subjects is that of female entrepreneurship in general. Female entrepreneurship as a discrete research area has expanded significantly since the 1980s, attracting concerted academic attention in recent years (Henry, Foss and Ahl, 2015). Extant literatures suggest that entrepreneurship is gendered, and that women face considerably more challenges in their entrepreneurial endeavours than their male counterparts. There are also marked differences in the level, type and scope of new ventures established by men and women. 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 start-up through to growth. 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), which may be an indication of the importance of organisational type in women's propensity to be entrepreneurial.

This is born out by a lack of examples either in academic literature or the media examples of women academics who have founded successful businesses or who have commercialised their research in other ways. One report which does address successful women entrepreneurs is by Weston-Smith (2015). She gives examples of not only women academic entrepreneurs in biotechnology but also female leaders in who are playing a key role in driving the growth of UK bioscience[3]. The implication of these broader range of women leaders means both a variety of successful role models and potentially more senior women with whom to network. An example of a woman academic turned business woman from a different discipline is Sarah Wood, Co-founder and co-CEO of video advertising technology (adtech) business *Unruly.* Wood has been voted UK Female Entrepreneur of the Year, named one of the 10 London-based 'Entrepreneurs to Watch' by Forbes, and was awarded the title of Digital Woman of the Year by Red Magazine in 2015. Her academic field rather than being a STEM subject was revolutionary literature and visual culture[4].

An explanation for the low level of female academic entrepreneurship found in the literature is that universities as an organisational type present particular inhibitors to female academic entrepreneurship. However, such suggestions need to be treated with some caution. There is a difference between the number of academic women who start a company and the number of academic women who are shareholders and, therefore, part of the entrepreneurship and commercialisation process. In this regard, Hewitt-Dundas (2015) emphasises two key points in relation to women's involvement in founding UK USOs (university spin-outs). First, as the number of founders in a UK

[3] http://www.mws-consulting.co.uk/wordpress/wp-content/uploads/2015/02/50-Movers-and-Shakers-in-BioBusiness-2015-final.pdf [accessed February 19 2016)
[4] http://startups.co.uk/how-to-succeed-as-a-technology-start-up/ [accessed February 18 2015]

USOs 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[5]. Where males are the main founder then the founding team has on average 3.0 members (sd=1.44) as compared to female-led UK USOs 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 share. This finding 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.

Moreover, the number of female shareholders as companies mature - for example 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 those spin-offs where the number of female shareholders is particularly high all belonged 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.

Patenting and licensing

While women academics in STEM subjects yield fewer patents than their male counterparts, there is evidence indicating that the quality and impact of women's patents is either equal or superior to those of male scientists. Furthermore, there is strong evidence that 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. Their findings revealed 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 number of academic researchers in the various

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

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 eleven US research universities disclosed or had disclosed once in 17 years. There was some increase over time but only in a minority of faculty members over the 17-year period from 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. The author argues 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. Furthermore, De Melo-Martin (2013, 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 (see also Whittington and Smith-Doerr, 2005). Similarly, Thursby and Thursby (2005) in their sample of US Science and Engineering Faculty at 11 major US research institutions 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.

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 (De Melo-Martin, 2013).

Patents, moreover - 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) caution against the use of patent data as an empirical measure of innovation, suggesting that the nature of the 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.

Explanations and effectiveness

The regional context

Explanations of why the regional context matters can have several different but associated dimensions. For example, networks are embedded in place-based social economic, cultural and political structures (Hanson and Blake, 2009). Some networks maybe linked 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). Mayer suggests that more research is needed on how networks are embedded in broader cultural discourses and structures, and how this affects potential agency for change. Brush et al. (2014) found that in the US, many fundable women entrepreneurs had the requisite skills and experience to lead high-growth ventures. In spite of this, women were consistently left out of the networks of growth capital finance, and appeared to lack the contacts needed to break through.

Human capital arguments suggest that levels of entrepreneurial activity are associated with education. High levels of formal education have been found to be associated with a propensity for entrepreneurship (Reynolds et al., 2001). In academia, this relationship does not hold true for women scientists. The explanation for this might be found in studies by Unger et al. (2011) and Marvel et al. (2013) who suggest that the relationship between education and entrepreneurship is more complex. For example, one individual can invest in education and experience, but 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. In this regard, 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 founded to be lacking in women (Ahl, 2006). This is necessarily interdependent with entrepreneurial motivation and intention (Micozzi et al., 2014).

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 - as well as different types of networks - than women. These types of networks are 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) (Granovetter 1973), 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 into account when prospecting for partners (Polkowska, 2012). This raises the question of why women may be less successful in selling research results to others, being selected for honours, or being invited to participate in start-up activity (Babcock and Laschevr, 2003; Murray and Graham, 2007).

Institutional analysis

It has already been suggested that the organisation context (industry and academia) seems to have an impact on women in STEM subjects' propensity to form companies or commercialise their research; one possible explanation for this maybe found in institutional analysis. Within the domain of social sciences, institutional analysis examines how institutions - i.e., structures and mechanisms of social order, as well as 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[6].

Studies have identified that women often lack institutional support for patenting (Etzkowitz et al., 2000; Fox, 2001; Long, 2001). Whittington and Smith-Doerr (2008), for example, found that women are more likely to patent in more flexible network-based organisational structures than in hierarchical organisations in both academia and industry. These authors analysed detailed data from a sample of academic and industrial life scientists working in the United States. They found that controlling for education- and career-history variables, women were less likely to patent than men. However, in biotechnology firms, industrial settings characterised by flatter, more flexible, network-based organizational structures, women scientists were more likely

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

to become patent-holding inventors than in more hierarchically arranged organizational settings in industry or academia. Moreover, discipline as an institutional factor is important. For example, Morgan et al. (2001) compared patenting and inventing activity of US scientists and engineers in industry and academia. They found that women in the US who patent are five times more likely to be life scientists than engineers, with the tilt being more pronounced for academia over industry. Overall, in academia women comprised 25% of holders of doctorates but only 11% of patenting activity.

Other research such as that by Corley and Gaughan (2005) has suggested that gender findings may be attenuated by the institutional setting. This is supported by Link et al. (2007) who 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: i.e., 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 explore 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 two kinds of gender disparity in commercial activity – both in involvement and in their decisions 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[7].

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

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

entrepreneurship workshop series was problematic. This was due to cultural differences in what women would need to know to become motivated to engage 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 involved 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 Nilsson (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 placed on entrepreneurialism for promotion and tenure, annual salary reviews and contributing to career development.

The 'impact' agenda in the UK is focusing more attention on commercialisation per se which may in turn bring about a reassessment of internal reward structures. Evidence from the US (Howe et al., 2014), Nilsson (2015) suggests that universities should adopt a gender sensitive approach to supporting academic entrepreneurship and commercialisation. This might take the form of a 'talent scout' who can offer a 'one-to-one analysis of research potential of the market place' (Howe et al., 2014) and role models of successful women academic entrepreneurs across the career spectrum profiled in events and on dedicated websites. Where there are examples of discussions in the media of science professors as entrepreneurs, these are often male dominated. In an article by Levine (2012)[8] all of the examples of successful academic entrepreneurs were men.

Moreover, other institutional measures to promote entrepreneurship include incubators also need to be made more effective in order to address gender differences in propensity to commercially exploit their university research. In their study, Lindholm Dahlstrad and Politis (2009) focused on university incubators for 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 considered the propensity for women academics in STEM subjects to be academic entrepreneurs or to commercialise their research through patents and licences. Drawing on relevant and contemporary scholarship, as well as extant reports,

---

[8] http://www.sciencemag.org/careers/features/2012/09/finding-balance-professorentrepreneur [accessed February 18 2015]

in the areas of entrepreneurship and gender, patenting and licensing, technology transfer and institutional analysis, the authors sought to uncover the particular circumstances under which women attempt to commercialise their research.

In quantitative terms, the evidence reveals significantly less commercialisation activity among female academics than among their male counterparts. 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 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) academic researchers' employment context and resources should be reviewed and improved so that gender differences are overcome. After all, women need to be able to first see themselves as valued employees, commercial actors and potential 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 and valuable insights for the study of women academics' commercialisation activity. Moreover, technology-based entrepreneurship by academics is not necessarily confined to STEM subjects. Studies which examine the broader scope of academic women's commercialisation activity would 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., Beblo, M. and Wolf, E. (2009) 'Berufliche Segregation', in *Geschlechterungleichheiten im Betrieb. Arbeit, Entlohnung und Gleichstellung in der Privatwirtschaft*, edited by Projektgruppe GiB, Berlin, pp. 89–139.

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

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

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

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

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

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

Brighetti, G. and Lucarelli, C. (2015) '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, 62–82.

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

Brush, C. G., Greene, P.G., Balachandra, L. and Davis, A E. (2014) *Diana Report Women Entrepreneurs 2014: Bridging the Gender Gap in Venture Capital* http://www.babson.edu/Academics/centers/blank-center/global-research/diana/Documents/diana-project-executive-summary-2014.pdf [accessed January 18, 2016]

Ceci, S. J. and Williams, W. M. (2011) 'Understanding Current Causes of Women's Underrepresentation in Science', *Proceedings of National Academy of Science of the United States*, 22, 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 Gaughan, M. (2004) 'Scientists' Participation in University Research Centres: What are the Gender Differences?', *Journal of Technology Transfer*, 30.4, 371–81.

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

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

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

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

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

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

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

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

Fox, M. F. (2001) 'Women, Science and Academia: Graduate Education and Careers', *Gender and Society*, 15.5, 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].

Granovetter, M. S. (1973) 'The Strength of Weak Ties' *The American Journal of Sociology* 78 (6): 1360–1380.

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

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

Henry, C., Foss, L. and Ahl, H. (2015) 'Gender and Entrepreneurship Research: A Review of Methodological Approaches', *International Small Business Journal*, on-line first.

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

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

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

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

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

Laznjak, J., Šporer, Z. and Švarc, J. (2011) 'Women in Science Commercialization: Looking for Gender Differences', *Gender, Technology and Development*, 15, 175–200.

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

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

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

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

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

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

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

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

Micozzi, A., Micozzi, F. and Pattitoni, P. (2014) ‘Fostering Female Entrepreneurship in Academic Spin-Offs’, in *University Evolution, Entrepreneurial Activity and Regional.Competitiveness*, ed. by D. Audretsch, E. Lehmann**,** M. Meoli, and S. Vismara, London: Springer, pp. 49–70.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 1. Some patterns evident in the literature

Indicator	General patterns	Location	Authors
Entrepreneurship – academic 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.