Ivory Tower vs. Business Incubator:

A study on academic entrepreneurship in the United Kingdom and its relationship to scientific productivity

Master Thesis by

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Abstract

Over the last years, academic entrepreneurship has become a widespread phenomenon and established itself as an important object of study among researchers focused on innovation, knowledge transfer, and university-industry cooperation. While many authors consider it beneficial, existing literature also provides some ground for concern, since deliberate commercialization activities of faculty members may not be necessarily compatible with pure scientific performance, which is positioned at the center of university-based system of knowledge production. Addressing such an ambiguity, this thesis investigates academic entrepreneurship within biosciences in the United Kingdom and studies its relationship to scientific productivity of university spinoff creators. Starting with a comprehensive literature overview, the paper develops a set of hypotheses about the nature of this relationship and then tests them by applying methods of descriptive and inferential statistics to a dataset of university researchers. Following this approach, this thesis presents a professional portrait of an academic entrepreneur and reveals a positive correlation between commercialization and publication activity. Studying this correlation deeper, the paper finds academic entrepreneurship neither necessarily beneficial nor harmful to scientific productivity by itself but reports on additional factors which may help interpret the positive relationship between two phenomena. As such, this research expands our empirical knowledge on the topic and helps derive a set of practical implications and policy recommendations.

Keywords: *academic entrepreneurship, scientific productivity, publication activity, university spinoff, United Kingdom, biosciences.*

1. Introduction

Over the last decades, the concept of a successful and socially desirable university transformed from an "ivory tower of intellectual pursuits and truthful thoughts" (Sharp, 1994, p. 148) to an engine of national or regional economic development (Klofsten and Jones-Evans, 2000). As a result, in addition to education and knowledge production, contemporary universities are increasingly offering inputs to innovations (Stern, 2004). For example, they provide information and ideas for new product and service development, serve as a training ground for highly qualified staff, and ultimately expand scientific knowledge base existing in public domain (Van Looy et al., 2004). As such, universities start being considered "an integral part of the […] regional network of public facilities that act as centers of attraction for individuals and enterprises" (Klofsten and Jones-Evans, 2000, p. 299).

Moreover, higher education institutions are becoming a significant source of entrepreneurial venture creation themselves, as students and faculty members start increasingly founding their own businesses to take advantage of innovative ideas and research findings. This academic entrepreneurship, i.e. deliberate commercialization activities of university-level researchers, is now considered an important and relatively efficient channel of technology transfer between universities and industrial organizations (Bekkers and Bodas Freitas, 2008) and, therefore, generally supported in the Western world.

Being actively studied in recent years (Rothaermel, Agung and Jiang, 2007), this still relatively new phenomenon failed, however, to get an unambiguous assessment from researchers. For example, focusing on institutional and social factors, many studies have paid little attention to individual-level characteristics that "shape the decisions of academics to engage in entrepreneurial activities" (Clarysse, Tartari and Salter, 2011, p. 1084), thus making the portrait of an entrepreneurial scientist relatively blurred. Without such knowledge, it may be difficult to properly promote and incentivize spinoff creation, attract and retain would-be entrepreneurs as faculty members, and institutionalize the phenomenon in the long term (Clarysse, Tartari and Salter, 2011).

But more importantly, it is still unclear whether academic entrepreneurship represents a truly win-win development. On the one hand, it stimulates national innovation systems, creates jobs, and improves universities' reputation (Shane, 2004). On the other hand, there is a concern that being too much focused on commercialization, an able scientist may compromise her research efforts in favor of the venture, thus becoming a less productive and successful researcher (Perkmann et al., 2013), which may constitute a negative externality for society.

Existing empirical evidence on the relationship between academic entrepreneurship and scientific productivity is rather mixed. Some studies argue for complementary nature of such a link (e.g., Gulbrandsen and Sm6eby, 2005; Stephan et al. 2007; Haeussler and Colyvas, 2011), while others find conflicting issues (e.g., Blumenthal et al., 1996; Campbell et al., 2002; Thursby and Thursby, 2002). Thus, there seem to be a fruitful room for further research that would shed more light on the issue in question and help us figure out whether academic entrepreneurship is, indeed, a beneficial phenomenon or whether it has its downsizes. If the former is true, implications from such research may be channeled into creation of stimulating policies and supporting institutions. While if the latter is the case, negative tradeoffs are likely to be admitted and remediation measures should be developed.

The present thesis addresses this problem and aims at contributing to our understanding of academic entrepreneurship and its link to scientific productivity, i.e. the amount and the quality of research output achieved by a university-level faculty member in a given unit of time. To reach this goal in a manageable yet fruitful way, scientific inquiry is limited to academic entrepreneurship in the United Kingdom and a single scientific area – biosciences.

The United Kingdom is considered one of the most scientifically productive nations and represents an advanced scientific system (OECD, 2010), acting as a platform for successful innovation and economic growth. Behind this is the academic system of UK universities, which is extremely competitive and entrepreneurial, since researchers are generally required to access resources through competition. Given these facts, the United Kingdom seems to represent a good place and environment to study academic entrepreneurship and its links to scientific productivity. It is here, where the proportion of venture founders is probably higher than average and, therefore, allows for intensive usage of quantitative and statistical methods. In addition, such a choice helps in controlling for certain nation-wide conditions and variables, thus making analysis both more transparent and potentially more insightful.

When it comes to biosciences as delimitation, biotechnology and adjacent fields have been found to be especially attractive for academic entrepreneurs (Shane, 2004), which is helpful in getting better exposure to the phenomenon in question and, again, allows to control for those variables that relate to differences among scientific areas.

That being said, following research questions are formulated to be answered by means of collection of extensive quantitative data on academic entrepreneurs and their non-entrepreneurial colleagues as well as subsequent statistical analysis:

1. What is a personal and professional portrait of an academic entrepreneur from the United Kingdom and what kind of ventures such entrepreneurs establish?
2. Are there any relationship between researchers' entrepreneurial experience and scientific productivity and what factors may contribute to such a relationship?

Conducted as such, the present study is able to make meaningful contributions to the existing literature. On a theoretical level, it provides a concise yet broad overview of the research on academic entrepreneurship and its links to scientific productivity. Considering different perspectives and dimensions, the thesis contrasts opposing views on the scientific problem in question, thus highlighting the most interesting avenues for further research.

From an empirical perspective, three issues seem beneficial. First, the analysis performed in the thesis increases the amount of knowledge existing on the topic. Second, some of the hypotheses formulated in Theoretical foundation are tested using variables – e.g., number of distinct co-authors and author's position in byline – which are rarely considered in the field. In addition, investigation of the link between academic entrepreneurship and scientific productivity includes not only naturally justifiable explanations but also some artificial factors, which is also not a widespread tactics. Finally, this work partly serves as external validation for some prior studies, thus helping the field move towards consensus. Specifically, it argues for non-conflicting relationship between venture founding and research and correlates the link with wider professional networks and bigger teams that academic entrepreneurs seem to possess.

The thesis proceeds as follows. Section 2 synthesizes existing literature on academic entrepreneurship, highlighting its historical development, internal nature, and contradictory links to scientific productivity. Based on that, a set of working hypotheses is developed, thus providing a theoretical foundation for further empirical investigation. Section 3 presents methodological setup, including high-level philosophical premises as well as concrete research design choices. Specifically, I describe details of data collection procedures and elaborate on variables and statistical methods used in data analysis. In section 4, the results of such a quantitative analysis are delivered. The section is structured around research questions, specified above, and working hypotheses, derived in Theoretical foundation. Finally, section 5 contains a brief discussion on the most important findings and concludes the thesis with some limitations and practical implications stemming from the analysis.

2. Theoretical foundation

Being a relatively new phenomenon, academic entrepreneurship has been actively studied in recent years (Rothaermel, Agung and Jiang, 2007). As a result, there emerged a few streams of literature which could now constitute a theoretical foundation for answering research questions proposed in Introduction. With regard to the first research question, it is important to investigate existing evidence on individual characteristics of academic entrepreneurs as well as their ventures, while the second question requires summarizing potential links between researchers' commercial activities and their scientific productivity. But before that, it seems reasonable to understand historical antecedents of academic entrepreneurship, since they provide a useful background for further discussion.

2.1. Historical development of academic entrepreneurship

A few decades ago, university science and its industrial applications were mostly considered autonomous yet interacting systems (Meyer, 2006) with a clear specialization in economic value creation. While universities were to a greater extent focused on conducting basic research, business organizations created their own labs and tried to use them in fundamental and – primarily – in applied scientific endeavors (Meyer, 2006). As put by Powell and Owen-Smith (1998), academic scientists were preoccupied with Research, while industrial ones were mostly doing Development, thus providing limited scope for consistent institutionalized interactions. In addition to that, two systems possessed (and still do) significant cultural differences. While university science aims at free circulation of knowledge through publications and consider priority a major incentive, industry players are incentivized by economic rents and, therefore, interested in secrecy and establishing exclusive intellectual property rights (Samsom and Gurdon, 1993; Powell and Owen-Smith, 1998; Haeussler and Colyvas, 2011).

However, a few political, economical, and social changes, occurred in the last 30 years, helped redesign science-industry relations and gave rise to the so called Triple Helix model of university favoring academic entrepreneurship. From a political perspective, major developments included Bayh-Dole Act (1980) in the United States and similar European legislation which allowed universities to pursue ownership of publicly funded inventions (Powell and Owen-Smith, 1998). It resulted in huge increase in university-driven patent applications and made licensing a significant revenue stream for academia, thus strengthening its relations with industry (Powell and Owen-Smith, 1998). In addition to that, the end of Cold War shifted focus of government science and technology policy to that favoring “competitiveness” and collaborative product development (Powell and Owen-Smith, 1998), which then required facilitating direct technology transfer from academia to industry through technology transfer offices (TTOs) that became prolific (Haeussler and Colyvas, 2011).

The above initiatives were further supported by economical factors. Dramatic time-collapse between discovery and application – especially in life sciences – offered academics previously non-existent opportunities to be involved in full-cycle research and development (Stephan and Levin, 1996), thus expanding their interest and motivation beyond basic research. The same development also fostered increased venture capital availability (Stephan and Levin, 1996), which, in turn, made it possible for small research-based companies to develop and bring their products to market. Furthermore, increasing knowledge specialization required firms to complement internal R&D activities with input from external sources (e.g., universities) that would "enable them to sense changes in technologies not necessarily only in areas in which they do business" (Meyer, 2006, p. 1647).

Finally, some endogenous changes inside universities made academic entrepreneurship a socially acceptable and even rewarding activity. For example, a substantial reduction in government-funded grants in the United States in 1980's and 1990's intensified competition among scientists, making them increasingly entrepreneurial (Stephan and Levin, 1996). In addition, a large number of universities established formal policies and procedures to help researchers transfer their knowledge through licensing or venture creation (Etzkowitz, 2003).

All in all, the above developments manifested a "second academic revolution" (Etzkowitz, 1990) and led to acceptance of the Triple Helix model of university-industry-government relations (Leydesdorff and Etzkowitz, 1996). Adding entrepreneurial objective as a third component to the mission of a university – after education and research – this model argues for "more involvement in economic and social development, more intense commercialization of research results, […] the institutionalization of spinoff activities […] among academics with respect to collaborative projects with industry" (Van Looy et al., 2004, p. 426). As a result, academic entrepreneurship – for example, via establishing spinoff companies – is now considered one of the most important channels of knowledge transfer and, therefore, actively supported and studied (Chrisman, Hynes and Fraser, 1995; Bekkers and Bodas Freitas, 2008).

2.2. Academic entrepreneurship: who, why, what

Apart from historical antecedents and current institutional environment, it is academic entrepreneurs themselves who are actively studied. For example, researchers look at their personal and professional attributes, incentives and motivations, and the nature of entrepreneurial output (O'Shea, Chugh and Allen, 2008). The aim of this research stream is to get a better understanding on (1) why academics, who usually experience no entrepreneurial pressure within university environment and who are assessed almost exclusively by their not necessarily commercially valuable research output, may also be willing to take part in spinoff creation and (2) what it means for higher education institutions and society as a whole. With this knowledge at hand, university officials and policy makers are supposed to adjust incentive systems and provide better institutional conditions, if academic entrepreneurship is desirable, or to seek for a proper remediation, if commercialization may conflict in some way with university mission. Within the present study, research on individual parameters of academic entrepreneurs seems also beneficial for establishing a base for comparison in subsequent empirical analysis.

Individual characteristics

One of the most important research streams on academic entrepreneurs deals with their individual characteristics and patterns of their behavior. More specifically, researchers study their prevalence as well as a number of demographic and professional variables such as gender, age, experience, and productivity.

Majority of existing studies shows that although academic entrepreneurship is becoming more and more prevalent, establishing their own companies is still relatively rare among university scientists. For example, literature overview by Perkmann et al. (2013) reports that the proportion of academics taking part in a commercial enterprise is generally below 10%. Gulbrandsen and Smeby (2005) find 7% of those involved in establishing an enterprise in their sample of 1,967 researchers from top Norwegian universities. Earlier surveys by Klofsten and Jones-Evans (2000) show that in Sweden and Ireland there are 12% and 19% (respectively) spinoff founders among academics (yet many entrepreneurs provide consulting services).

There is also a consensus in the literature with regard to gender, since there is a clear tendency for academic entrepreneurs to be males (Klofsten and Jones-Evans, 2000; Haeussler and Colyvas, 2011; Perkmann et al., 2013). The reasoning behind this fact is twofold. On the one hand, female researchers are generally underrepresented among faculty members (Haeussler and Colyvas, 2011), have less access to research resources, and get fewer senior level appointments (European Commission, 2006). On the other hand, literature on general entrepreneurship also suggests that women are less likely to be involved in venture creation (Greene, 2001; Robb and Coleman, 2009; Hipple, 2010).

Many researchers find a positive link between scientist's age or seniority and the likelihood of her becoming an entrepreneur (Stephan et al., 2007; Haeussler and Colyvas, 2011; Perkmann et al., 2013). These studies picture an academic entrepreneur as a relatively experienced researcher who has already established in her reputation and has a broader stock of accumulated human and social capital (Stephan and Levin, 1992). Putting it differently, senior faculty members usually have more opportunities for network creation than their younger colleagues (Perkmann et al., 2013) and exercise them for a longer period. In addition, scientific reputation – which is considered beneficial for venture creation – is to some extent a function of time and tends to grow during one's career (Bercovitz and Feldman, 2008). Finally, it is argued that tenured researchers obtain employment security and, therefore, become more inclined to pursue not only scientific but also commercial opportunities (Stuart and Ding, 2006). Unlike them, younger faculty members are supposed first to earn their tenure by focusing on research and publication activity (Stephan et al., 2007).

Finally, there is evidence that academic entrepreneurs are usually excellent researchers with numerous impactful publications. Literature overview by Perkmann et al. (2013), for example, concludes that commercialization is more likely "to be pursued by individuals that are more scientifically productive than their colleagues" (p. 427), while Zucker, Darby and Armstrong (1998) report that almost every third scientific "star" in their sample of Californian biotechnology researchers was either affiliated or linked to an enterprise.

All in all, when it comes to individual characteristics of academic entrepreneurs, one may conclude that they tend to be highly productive males with significant experience and seniority reflecting accumulated human and social capital.

Motivation, incentives, and choices

As for the factors influencing researcher's choice to become an entrepreneur, current literature emphasizes motivating factors, personal attributes, university-related and external environmental issues, which all play a role in predicting one's commercial inclination.

From a motivational perspective, it is argued that entrepreneurship may be sought by some academics because it allows them to advance their own research agendas and pursue fundamental or more applied ideas up to and beyond the point of product development (Stephan and Levin, 1996). In addition, venture creation may become an important source of research funding, since university spinoffs tend to be supported by venture capital (Gulbrandsen and Smeby, 2005; Lawton Smith and Ho, 2006). As such, academic entrepreneurship may help researchers continue with the project even in the absence of traditional funding opportunities such as grants. Finally, venture creation can be considered another way of self-realization for a scientist, which rests upon her self-efficacy (Clarysse, Tartari and Salter, 2011) and goes beyond research and teaching responsibilities.

Besides this motivation, there are also certain personal attributes that make an academic more inclined to commercialization. For example, Clarysse, Tartari and Salter (2011) argue that prior entrepreneurial experience and strong opportunity recognition abilities are good predictors of one's involvement in academic entrepreneurship.

An even bigger research stream is concerned with organizational and social factors that simplify and promote spinoff creation. One of the most studied areas here is the role of technology transfer offices (TTOs) established by universities in increasing entrepreneurial activity of faculty members. Supposed to assist scientists in securing intellectual property rights, attracting venture capital, and performing administrative tasks (Roberts and Malone, 1996), TTOs are aimed at creating conducive environment in which it becomes easier for researchers to overcome hassles of establishing an operational business (Clarysse et al., 2005). Such environment is believed to lower barriers for technology transfer, and, indeed, efficiently operating TTOs have been found to significantly improve spinoff creation and patenting rates (Debackere, 2000; Colyvas et al., 2002; Markman et al., 2005).

More recent empirical work, however, either presents mixed results or does not find a clear and consistent impact of TTOs (Clarysse, Tartari and Salter, 2011). Instead, it attributes venture creation within academia to social norms and practices existing in universities and departments. For example, Stuart and Ding (2006, p. 99) show that "faculty members were more likely to become entrepreneurs […] when they worked in university departments that employed other scientists who had previously ventured into the commercial sector." Similarly, Bercovitz and Feldman (2008, p. 86) argue that "social learning and local context influence an individual's decision to follow strategic initiatives and participate in new activities" (incl. academic entrepreneurship).

Among other organizational factors influencing one's involvement into spinoff creation, university resources and capabilities are also considered important. It has been shown that high levels of university R&D expenditures (incl. industrial funding) positively correlate with increased entrepreneurial activities (O'Shea, Chugh and Allen, 2008), while university's focus on biological sciences, computer science, and chemistry-related disciplines also seems to have a positive and statistically significant effect on spinoff formation rates (O'Shea et al., 2005).

Finally, environmental factors – such as venture capital availability, appropriation regime, and regional infrastructure – are supposed to affect researcher's involvement in academic entrepreneurship (O'Shea, Chugh and Allen, 2008). Being one of the strongest resource constraints faced by universities, venture investments are usually considered more important than internal funds by founders (Wright et al., 2006). Thus, universities located in regions with higher density of "angel" or institutional investors or those with established contacts in venture community are more likely to demonstrate more active spinoff creation by faculty members (Sorenson and Stuart, 2001). When it comes to appropriability, industries and territories with high levels of patent protection (e.g., pharmaceuticals and biotechnology) create more conducive environment for entrepreneurship by lowering risk and uncertainty about commercial potential of the venture (Nerkar and Shane, 2003).

In summary, existing research pictures a complex system of incentives and supportive processes behind academic entrepreneurship. As shown above, it includes not only scientists' personal motivation for venture creation but also factors in their immediate and external environment.

Ventures' characteristics

Now, when the individual attributes of academic entrepreneurs as well as motivation behind their choices are considered, it is reasonable to look at the companies these researchers establish. More specifically, it is the research on their business nature and success rates which seems important for understanding what kind of economic impact and contribution such companies tend to have and whether it justifies the effort.

From existing literature, it seems that academic entrepreneurs tend to start companies which are mostly involved in production or service providing, since the number of purely consulting-based firms is reportedly low (Lawton Smith and Ho, 2006). Biomedicine and IT are the most attractive industries for university spinoffs because they are technology-driven, rapidly developing, and, therefore, provide more opportunities for economic value creation (Shane, 2004). Companies' size, growth rates, revenues, and product generation are usually modest (Lerner, 2005) but seem to grow over time (Lawton Smith and Ho, 2006). Finally, venture capital followed by business angel investors is the most prevalent source of financing for such firms (Lawton Smith and Ho, 2006).

As for success rates, there is evidence in the literature that university spinoffs are generally relatively successful and academics, indeed, contribute to their economic performance. For example, Stephan and Levin (1996) describe cases of such profound university-related companies as Genetech and Regeneron and report a high proportion of biotech-pharmaceutical ventures that went public in 1990's. A study by Pressman (2002) shows that out of the university spinoffs formed in 1980-2001, 65% were still operational in 2001. Finally, Lawton Smith and Ho (2006) find that survival rate for academic ventures from Oxfordshire, UK (incl. those formed at the University of Oxford) is 90% and well above the national 3-year firm survival rate.

Scientists' contribution to success of their companies is believed to originate from their human capital, i.e. tacit knowledge and signaling, and social capital, i.e. network of connections with external environment (Murray, 2004). And these claims find empirical support in, for instance, Zucker, Darby and Armstrong (1998) who report that firms collaborating with "star" scientists tend to be bigger and more productive than those without such input.

Overall, existing literature suggests that companies founded by academic entrepreneurs seem to be technology-driven, modest in size, backed by venture capitalists, and relatively successful in terms of survival rates. Thus, they are considered an important channel of technology transfer and generally beneficial for national economies (Bekkers and Bodas Freitas, 2008).

2.3. Academic entrepreneurship and scientific productivity

As mentioned earlier, Triple Helix model of university-industry-government relations is now generally accepted in Western societies, and universities are supposed to encourage entrepreneurial activities of their faculty members. Nevertheless, it is still argued in the literature whether academic entrepreneurship is an absolutely positive development or whether there are some drawbacks of researchers becoming venture founders (Perkmann et al., 2013).

More specifically, there is a discussion on the complementarities and potential conflicts between research-related and entrepreneurial parts of university's mission. In other words, scientists are trying to see whether commercialization activities performed by faculty members in some way affect their traditional performance metrics summarized by the term "scientific productivity".

Although there is no clear consensus on precise definition, scientific productivity in academic context is usually defined as a combination of the quantity and the quality of research output delivered by a faculty member in a given unit of time (Kreiman and Maunsell, 2011; Sahel, 2011). Being actively studied since 1960's (Lissoni et al., 2011), it is usually operationalized by using common bibliometric measures such as number of peer-reviewed publications, different citation rates (e.g., h-indices), and impact factors of journals where publication takes place (Petersen, Wang, and Stanley, 2010). It is assumed that the most valuable and productive research leads to a higher publication activity and greater external attention and recognition by means of citations. In addition, it allows authors to choose the most prestigious scientific journals, thus increasing their coverage and reputation (Kreiman and Maunsell, 2011).

While representing an interesting object of study, scientific productivity is also an integral part of incentive systems in contemporary universities. For example, it has been formally established and empirically confirmed that publication activity and citation rates are directly associated with academic promotion, recognition, and remuneration (Long, Allison and McGinnis, 1993; Moore, Newman and Turnbull, 2001; Lissoni et al., 2011). Faculty members are not only required to publish more and better papers but are usually interested in publications themselves. This is because in traditional academic environment publishing is one of the limited number of ways to bring ideas to the world and take credit for the work that has been performed by establishing one's priority (Powell and Owen-Smith, 1998).

Therefore, factors influencing one's scientific productivity represent a fruitful area of study which may generate useful implications for policy makers at national or university levels and for specific individuals as well. With regard to academic entrepreneurship, assessing its relationship to scientific productivity is also important. If two phenomena reinforce each other, there is no need to worry about universities becoming more entrepreneurial and spinoff creation may actually be encouraged. But if there is a tradeoff, it is crucial to understand when and to what extent productivity might be compromised in favor of commercialization and what a balanced mix of the two could look like. In addition, if entrepreneurial agenda is, indeed, going to become integral to higher education institutions of the future, they may start slowly shifting incentive systems towards those where scientific productivity would be only one of the most critical factors (especially if publication and commercialization activities turn out to be incompatible).

Existing literature provides theoretical justification and empirical evidence for both positive and negative relationship between academic entrepreneurship and scientific productivity. Therefore, it helps formulate a number of hypotheses to be tested later on in this study.

Complementarities between academic entrepreneurship and scientific productivity

Being previously autonomous, university science and industry are now much more interacting systems due to specific political, economical, and social changes, described earlier in the thesis. As a result, one may expect them to achieve a number of synergies for mutual benefit. On the one hand, as knowledge creation institutions, universities are supposed to provide industry with input to innovations, thus fostering economic development (Stern, 2004). And this interaction becomes especially important given a clear trend towards open innovation model which requires firms to actively look for external support in developing new products and services (Chesbrough, 2003). On the other hand, collaboration with industry promises science access to additional resources and capabilities as well as an opportunity to do full-cycle research and development, which is potentially more fruitful (Stephan and Levin, 1996).

Having this picture in mind, some researchers believe that academic entrepreneurship – an important knowledge transfer mechanism – is positively correlated with one's scientific productivity and many of them find empirical evidence supporting this argument. For instance, Van Looy et al. (2004) report that scientific excellence and entrepreneurial performance reinforce each other because academics working in semi-entrepreneurial divisions at the Catholic University of Leuven "never publish less than their colleagues not involved in divisional activities" (p. 435) and the difference increases over time. Similarly, Haeussler and Colyvas (2011) argue that traditional academic publication activity and commercial activity "go hand in hand", since the number of publications has a positive and statistically significant effect on the degree of commercialization. Additional evidence comes from prolific research on academic inventors and their patenting activity, which is considered a part of commercialization and a good proxy for further venture creation. A positive link between publications and patenting is, for example, established by Breschi, Lissoni and Montobbio (2007), Stephan et al. (2007), and Fabrizio and Di Minin (2008), while absence of any negative tradeoff is reported in Agrawal and Henderson (2002). Overall, literature review by

Perkmann et al. (2013) suggests that academics involved in commercialization publish more and better papers than their non-entrepreneurial colleagues.

Proceeding further with this conclusion, it is now interesting to address potential mechanisms behind it. Existing literature mentions additional funding, research freedom, and utilization of social capital as the most important factors making higher productivity for academic entrepreneurs possible.

One of the most important advantages available for academic entrepreneurs is access to additional financial resources, since most of spinoffs – especially in life sciences and biotechnology – are usually backed by significant venture investments (Lawton Smith and Ho, 2006). Linking this issue to scientific productivity, Fabrizio and Di Minin (2008, p. 917) state that "patenting and the subsequent [...] licensing revenue and industry involvement may allow a university researcher access to additional funding [...] that he could spend on additional equipment, researchers, and junior faculty members, all of which could contribute positively to the publications and patents produced by the lab." Although empirical studies revealing positive influence of additional funds obtained through academic entrepreneurship are scarce, it is still possible to justify it indirectly. For example, Blumenthal et al. (1996), Godin (1998), and Gulbrandsen and Smeby (2005) show that university researchers with funding from industry, indeed, produce more scientific publications than their colleagues without such funding.

Another possible side benefit of academic entrepreneurship, which is related to the previous one, is a higher level of research freedom that an academic entrepreneur may obtain. According to Stephan and Levin (1996), privatization of scientific findings allows scientists more flexibility in advancing their own agendas as they become no longer limited to what grant providers and university itself consider important and worth pursuing. The authors even argue that some of the well-known ventures would not have been created, if their founders had relied on agendas of grant-awarding agencies. Another supporting argument is developed by Fabrizio and Di Minin (2008) who point out that working on commercialization – whether it is a patent application or spinoff creation – university researchers are likely to "learn or encounter challenges that point to new research questions" (p. 917). While these avenues might not be necessarily compliant with the agenda desirable by the university or the department, they could still be pursued through an independent company. In other words, by becoming an academic entrepreneur a scientist may diversify sources of funding and expand the portfolio of possible research projects beyond what is available for her non-entrepreneurial colleagues[1].

Yet another potential source of higher scientific productivity originates from entrepreneurs using their social capital, i.e. network of connections with external environment (Murray, 2004). The nature of this factor is twofold. On the one hand, there are reasons to believe that entrepreneurs tend to possess relatively larger professional networks. On the other hand, social capital has been found positively related to scientific productivity.

As mentioned earlier, academic entrepreneurs seem to be slightly older and more experienced than their non-entrepreneurial colleagues. Given that research collaboration tend to increase with one's age or seniority (Link, Siegel and Bozeman, 2007; Haeussler and Colyvas, 2011), it is then reasonable to expect venture founders to possess relatively larger professional networks. In addition to that, Bekkers and Bodas Freitas (2008) as well as Perkmann et al. (2013) report a positive link between frequency of researcher's collaborating activities and her involvement in commercialization.

When it comes to collaboration's impact on scientific productivity, there seems to be a general consensus that this link exists and is positive. For example, in their literature review, Bozeman, Fay and Slade (2013, p. 4) mention a number of studies that "have provided strong evidence that collaboration tends to enhance productivity of scientific knowledge." The reasoning behind such a relationship usually includes improvements in one's absorptive capacity that are achievable through numerous professional interactions (Cohen and Levinthal, 1990), which, in turn, leads to more productive and potentially successful research. In addition, there is empirical evidence that strong motivation behind collaborative research is access to resources such as additional funds

[1] For objectivity's sake, it should be noted that the opposite argument regarding research freedom may also be plausible. Indeed, focusing too much on the venture, an academic entrepreneur is likely to spend less time on scientific endeavors (Azoulay, Ding and Stuart, 2004) or to specialize in a more narrow scientific area (Van Looy, 2004; Gulbrandsen and Smeby, 2005), thus seemingly reducing her freedom. At the same time, such a situation would, to my mind, represent a specific personal choice, while freedom is rather the ability to make such choices in the first place.

and equipment (Lee, 2000; Krabel and Mueller, 2005), which may also be critical for one's productivity.

Last but not least, benefits stemming from teamwork may be considered in relation to scientific productivity. Although establishing a company may be attributable to a single entrepreneurial individual, running a business is usually a collective effort (Tarricone and Luca, 2002), especially if it requires fast and productive research and development. Thus, team size (obviously in addition to its quality) may be one of determinants of scientific output for a given university spinoff, which is in line with the existing literature. On the one hand, studies find university research becoming increasingly team-based and establish a link between active collaboration and bigger teams over time (e.g., Wuchty, Jones, Uzzi, 2007). On the other hand, a number of papers show that team's size is positively associated with scientific output and influence because a group of collaborating researchers is able to build on greater collective knowledge and effort (e.g., Haeussler and Colyvas, 2011). Given higher prevalence of collaborative strategies among academic entrepreneurs, one may then expect them working in bigger teams and, therefore, being more scientifically productive than their lonely colleagues, whether entrepreneurial or not.

It is easy to see that factors presented so far provide natural explanations for entrepreneur's ability to combine productive research with commercialization activities. In other words, indeed, there may be something in or around academic entrepreneurship that makes founders better researchers. Theoretical background would not be, however, comprehensive enough without including non-natural factors which attribute higher publication or citation rates to what I call artificial mentioning.

According to academic norms and principles, only those scientists who significantly contributed to the research described in the publication are supposed to take credit for it by means of becoming co-authors (ICMJE, 2007). In addition, the order in which these co-authors are mentioned in the byline is supposed to reflect the importance of one's contribution. The first position is usually reserved for the one who performed the major part of the work, while the last one gives credit to the most senior team member or the one who provided funding (Zuckerman, 1968; Lissoni, Montobbio and Zirulia, 2013).

However, existing literature points out that sometimes factors that are different from one's contribution are taken into account when a list of co-authors is created. For example, a highly renowned – honorary – scientist is likely to become a co-author even with marginal participation in the project (Flanagin et al., 1998; Mowatt et al. 2002; Bates et al., 2004). It is also possible that a leader of a research team or a scientific executive may be mentioned as a co-author just because of her seniority in the organization (Lissoni, Montobbio and Zirulia, 2013). In addition to that, there is ample evidence suggesting existence of the Matthew effect in science, according to which "eminent scientists […] are given disproportional credit in cases of collaboration" (Merton, 1968, p. 57). Given that academic entrepreneurs tend to be highly productive and renowned senior faculty members and usually hold top positions in their companies, it is then reasonable to believe that their productivity may be partially inflated by artificial mentioning.

In summary, the above arguments support existence of a positive relationship between academic entrepreneurship and scientific productivity. Thus, they may serve as a theoretical foundation for further analysis. But before it is possible to generate all relevant hypotheses to be tested later on in the thesis, plausible explanations for a negative link between two phenomena should also be considered.

Conflicts between academic entrepreneurship and scientific productivity

Despite a clear trend towards intensive interaction, university science and industrial business still represent relatively distinct worlds which are built around different objectives, incentives, and cultures. Moreover, some of the issues are directly contradictory to each other and are, therefore, able to affect the relationship between one's scientific productivity and academic entrepreneurship.

The first important distinction is around objectives. While business and industry are clearly interested in creating and capturing economic value (Haeussler and Colyvas, 2011), the goals of universities – even under Triple Helix model – are significantly more focused on knowledge creation and its distribution (Stern, 2004). From a macroeconomic perspective, there seems to be no direct contradiction between the two as science and industry are necessary for and complementary to nation's economic development. On the level of an individual, however, it may be relatively difficult to avoid certain tradeoffs and do both parts equally effective (Stern, 2004), as will be exemplified below.

Another huge difference between science and industry is what drives and motivates individual actions. Academics are intrigued by complicated scientific puzzles (Stephan and Levin, 1996), aim at establishing priority and reputation by means of peer-reviewed publications (Powell and Owen-Smith, 1998; Haeussler and Colyvas, 2011), and care less about monetary rewards (Stern, 2004). Universities, in turn, offer a compatible incentive system, whereby promotion, recognition, and remuneration are to a greater extent dependent on the quantity and the quality of one's scientific output formalized in publications and grants (Reskin, 1977; Moore, Newman and Turnbull, 2001; Lissoni et al., 2011). Entrepreneurial agenda in such a system may be present – especially in the era of Triple Helix model of university – but it is unlikely to have a decisive influence on everyday professional choices as academic entrepreneurship is still a quite rare phenomenon (Perkmann et al., 2013).

Unlike academics, businessmen are known to be motivated by financial perspectives of their ventures as well as by entrepreneurial experience itself (Hamilton, 2000). Such choices are then further incentivized by market dynamics that is governed by laws of economics and promotes those who are able to create higher value and/or appropriate it faster than others. Although scientific output may also be important for entrepreneurs – especially when it comes to research and development – it is not the new knowledge itself but its commercial potential that is appreciated (Powell and Owen-Smith, 1998).

As one can imagine, the above motivations and incentives may call for quite opposite actions. For example, priority-based system, established in science, requires free knowledge sharing and peer review, while appropriation of economic value, pursued in industry, is usually about excludability and, therefore, secrecy. Thus, an academic entrepreneur may find it impossible to satisfy the requirements of both worlds and will have to choose what to pursue first – a publication and scientific recognition or a patent and commercialization potential.

Finally, both objectives and motivations contribute to formation of relatively different cultures. University research is about consensus-based decision-making, employment security, and flat hierarchies, while business ventures require subordination or undivided authority and are inherently risky (Samsom and Gurdon, 1993). And when these cultures collide in the head of an academic entrepreneur, a tradeoff is highly likely and some of the values should be compromised in favor of others (Samsom and Gurdon, 1993).

Having studied the above issues, researchers found mixed empirical evidence. It is, however, possible to mention a few relatively supported explanations for why academic entrepreneurship may have a negative effect on one's scientific productivity. They are research slowdown, substitution effect, and skewing problem.

First, it is believed that secrecy and excludability, which are so prevalent in business world, are likely to force academic entrepreneurs to delay publications until intellectual property rights for the invention in question are properly secured (Stephan et al., 2007; Fabrizio and Di Minin, 2008). Given a relatively long processing time for a patent application, it may, indeed, decrease publication rates around the time of venture creation, thus seemingly slowing down one's research activity.

Empirical evidence in favor of this hypothesis has been presented by several authors. Having surveyed life science faculties and companies supporting them, Blumenthal et al. (1996) find delaying publications and restricting information sharing quite common due to sponsor companies' need to file a patent application. Thursby and Thursby (2002) mention that industry partners require on average a four-month delay in publications and stipulate this directly in the contracts with universities or academics. Finally, Campbell et al. (2002) report that more than 20 percent of those in the sample withheld information from colleagues to protect potential commercial interests. In other words, there are, indeed, reasons to expect that entrepreneurs' scientific productivity may be pushed down by their venture experiences.

Another potential source of concern is so called substitution effect. Given that commercialization activities, such as patenting or venture creation, are time consuming, one may expect that academic entrepreneurs would have to shift the balance of their time and attention toward administrative tasks and away from direct research (Azoulay, Ding and Stuart, 2004; Fabrizio and Di Minin, 2008). This, in turn, is likely to have an adverse effect on scientific productivity, unless the research team is big enough and the entrepreneur in question is able to delegate efficiently.

Empirical evidence on this issue is, however, scarce, which is most likely because of objective methodological difficulties. At the same time, Gulbrandsen and Smeby (2005) touch upon the problem indirectly. Although the authors find complementary relationship between publishing and some of entrepreneurial activities, they failed to establish a link between publishing and venture creation and partially attributed it to the "time squeeze" problem.

Finally, a skewing problem may contribute to negative relationship between scientific productivity and academic entrepreneurship. Being involved in commercialization, academic entrepreneurs are believed to be more interested in shifting their focus from basic research to applied one, so that they could create a better product offering to the market (Van Looy, 2004; Gulbrandsen and Smeby, 2005; Perkmann et al., 2013). However, research for competitive advantage at the expense of research for knowledge (Powell and Owen-Smith, 1998) is likely to change patterns of one's productivity. On the one hand, applied science is more short-term oriented (Florida and Cohen, 1999). On the other hand, it may be less influential (Fabrizio and Di Minin, 2008) as it focuses on a limited set of technologies and theories behind them. Thus, reduction in both publication and citation rates may be expected, unless the person is able to increase applied research without compromising basic one.

Empirical evidence on this problem is mixed. Blumenthal et al. (1999) show that academics' research agendas are indeed influenced by project's commercial potential, while Fabrizio and Di Minin (2008) find negative impact of patenting on citation rates, once it is a repetitive procedure. At the same time, Van Looy et al. (2004) report that entrepreneurial – and more applied – researchers even more productive than those who focus on basic research. No clear conflict between two types of science in terms of productivity is also shown in Gulbrandsen and Smeby (2005). In other words, while being a theoretically reasonable concern, the skewing problem may have a complicated and, therefore, less clear influence on one's scientific productivity.

Now that different factors around both positive and negative link between academic entrepreneurship and scientific productivity are considered, it is possible to develop following working hypotheses to be tested later on in the thesis:

> *Hypothesis 1a: Academic entrepreneurs start publishing more papers after founding a company.*
>
> *Hypothesis 1b: Academic entrepreneurs start publishing fewer papers after founding a company.*
>
> *Hypothesis 2: Academic entrepreneurs possess a larger professional network (have more professional contacts and connections).*
>
> *Hypothesis 3: Academic entrepreneurs work in bigger research teams.*
>
> *Hypothesis 4: Academic entrepreneurs are subject to artificial mentioning.*
>
> *Hypothesis 5: Academic entrepreneurs delay publications during the period around venture creation (publish fewer papers around the time of company's foundation).*
>
> *Hypothesis 6: Academic entrepreneurs make a shift from basic to applied science around the time of company's foundation.*

As one can see, Hypotheses 1a and 1b are competing and test a direct link between academic entrepreneurship and scientific productivity, meaning that a spinoff creation by a faculty member may be either positively or negatively correlated with indicators of her subsequent publication performance. Hypotheses 2-6 check this link rather indirectly and consider a set of covariates that are likely to interact with both studied phenomena.

3. Methodology

Being relatively complex, the phenomena of academic entrepreneurship and scientific productivity require a thorough methodological setup so that one could perform proper analysis leading to important and externally valid implications on their interrelations. In this section, the overall research philosophy and specific methodological choices in data collection and data analysis, stemming from this philosophy, are described, thus providing a robust and scientifically justified foundation for subsequent analysis.

3.1. Philosophical premises

Given the nature of the research questions, existing literature on academic entrepreneurship and scientific productivity, and author’s personal preferences, positivism seems to be the most appropriate research philosophy to provide answers to the questions formulated in Introduction. Being in some sense similar to those of physical and natural scientists, the present paper developed so far a set of hypotheses that now need to be tested, leading to the further development of theory and establishing law-like generalizations. And it is exactly where positivism can be of great help (Thornhill, Saunders and Lewis, 2008). In addition, being independent of and not affecting or being affected by the subject of the research, it is possible to undertake a scientific inquiry in a value-free way, which is, again, compatible with positivistic paradigm (Thornhill, Saunders and Lewis, 2008).

That being said, deduction appears an obvious choice when it comes further to the research approach. While it might not be so important with regard to the first research question, the second one directly implies existence of a relationship between academic entrepreneurship and scientific productivity and, therefore, requires collection of operationalizable data, testing of a hypothesis, and interpretation of results. In other words, it resembles a deductive process whereby a logically certain conclusion is reached from one or more revealed premises (Thornhill, Saunders and Lewis, 2008).

Finally, the above choices seem to be better supported by collecting mostly quantitative data with both cross-sectional and longitudinal elements. Quantitative nature of data allows using methods of descriptive and inferential statistics and, therefore, promises objective results with sufficient explanatory power. Cross-sectionality stems from natural time constraints and is useful for investigating current state of academic entrepreneurship and its relationship to productivity, while longitudinal data helps time-series analysis, which is necessary to understand historical trends.

All in all, these philosophical premises imply a highly structured methodological setup. It is supposed to rely on sufficiently large samples of objective data coming from observable social reality and ability to perform different measurements and calculations proposed by generally acknowledged statistical methods. Such a setup, which is used in the thesis for data collection and data analysis, is described in details below.

3.2. Data collection

The nature of the research questions, specified in Introduction, and a set of hypotheses, formulated in Theoretical foundation, require gathering data on individual university researchers with and without entrepreneurial experience. More specifically, it is necessary to collect their demographic and career-related characteristics as well as information on scientific productivity. To improve likelihood of manageable yet fruitful analysis, the United Kingdom has been chosen as a base for data collection and researchers who worked for the University of Cambridge (later referenced also as Cambridge) in 2001 have been considered for creating an analytical sample. Furthermore, data collection has been strategically limited to biosciences[2].

Providing a significant contribution to the advances of the national scientific system, universities in the United Kingdom are considered highly productive research institutions and represent extremely competitive and entrepreneurial environments (OECD, 2010). Being to a great extent autonomous in terms of budget, recruitment, and scientific agenda, they operate under a well-established system of government funding, which supports a range of university-related commercial activities, including academics' commercial ventures (Mustar and Wright, 2010). Thus, the UK seems to represent a fruitful ground for studying academic entrepreneurship and create conditions necessary for obtaining a large enough sample of spinoff founders for further quantitative analysis. In addition, such a choice helps control – to some extent – for nation-wise variables which should have otherwise been considered separately.

When it comes to my focus on those working for Cambridge in 2001, this tactics stems from data collection procedures specified below and seems appropriate, since the

[2] It should be noted that although being reasonable, these methodological choices potentially limit external validity of implications stemming from subsequent analysis. Therefore, they do not represent perfect data collection setup but seem sufficient for the purpose of answering research questions.

university is considered one of the most entrepreneurial institutions in the United Kingdom (OECD, 2012). In addition, as one's employment status in 2001 does not necessarily determine current professional situation and researchers tend to move between universities, studying those employed by Cambridge in 2001 will ultimately allow for covering several higher education institutions, making analysis more representative[3].

Finally, genetics, biotechnology, and other related fields have taken my primary attention because they have been found especially attractive for academic entrepreneurs (Shane, 2004), which is, again, beneficial for obtaining a better exposure to the phenomenon in question.

Given the above propositions, data collection for the present project involved four major stages. It started with obtaining a list of relevant faculty members that would then constitute general population, i.e. source for creating an analytical sample. This was performed through Research Assessment Exercise 2001 (RAE) (www.rae.ac.uk/2001/), which is "a peer review exercise to evaluate the quality of research in UK higher education institutions and used to enable […] funding bodies to distribute public funds for research selectively on the basis of quality" (RAE, 2001). Based on the information submitted by the University of Cambridge for the unit of assessment #14 (Biology), a list of 222 unique last names and initials was obtained for further processing. In other words, so many faculty members were employed by Cambridge in 2001[4] in the respective scientific field, which includes departments of Biotechnology, Biochemistry, Genetics, Zoology, and Plant Sciences. And the fact that they represented nearly all academics in those departments ensured more variability and better representativity of the final sample.

After getting the list, general demographic, career-related, and venture-related data were obtained via comprehensive Internet search for each faculty member, which took about 60 working hours to complete. Using publicly available CVs, personal webpages (incl.

[3] Faculty members from the sample collected worked for more than 90 higher education institutions during their careers, incl. 32 universities located in the United Kingdom.

[4] Given that RAE is conducted every seven years, 2008 edition could have also been used for data collection purposes. However, the choice of 2001 edition provided more history of professional mobility among faculty members as they could have moved to other organizations by now. And such mobility was of interest to this study.

LinkedIn profiles), official biographies, and other secondary sources, it was possible to collect comprehensive enough information on age, gender, education, employment history, entrepreneurial status (and venture characteristics if relevant), etc.[5] for 53 researchers (23.9% of the list), who, therefore, constituted initial analytical sample.

In order to expand the sample even further, researchers with available email addresses were contacted by my supervisor – Prof. Valentina Tartari – and asked to provide a copy of their CVs. This move resulted in 21 more sample objects: ten subjects were added after initial communication and 11 more after a gentle reminder. Five contacted persons deliberately declined the request. Thus, the achieved response rate was 18.5%.

All in all, the second stage of data collection resulted in the sample of 74 faculty members (33.3% of the list) with comprehensive enough demographic and career-related information (incl. ten academic entrepreneurs). Although quite small, this sample is large enough to represent 95% confidence level with a 6% margin error in describing general population, as measured using the procedure proposed in Thornhill, Saunders and Lewis (2008). Therefore, it seems sufficient for further quantitative analysis and general implications on academic entrepreneurs. High-level summary of the data collected, presented in Table 1, shows no concerning differences between two collection procedures (web search vs. emails).

Table 1. Overview of the data collected

Variable	Total		Via Web Search		Via Emails	
	#/Avg	S.D.	#/Avg	S.D.	#/Avg	S.D.
Sample size	74	–	53	–	21	–
Females	15	–	8	–	7	–
FRS Fellows	16	–	12	–	4	–
Entrepreneurs	10	–	10	–	0	–
Age (n = 30)	59.4	11.7	59.8	11.6	58.9	11.7
No. Years since PhD	28.6	10.5	28.1	10.4	29.8	10.5
No. Employers	3.2	1.5	3.2	1.4	3.4	1.6

[5] Full list of specific variables stemming from the data collected and used in subsequent analysis is presented later on in the section.

During the third stage, a list of all publications was retrieved for each person in the sample via Scopus database (www.scopus.com). Moreover, for each title, information on names of co-authors, name of the source, year of publication, number of citations, and names of affiliations was also collected. Additionally, these data were matched with Journal Metrics database (www.journalmetrics.com) to get SNIP and SJR values for each relevant publication from 1999 to 2012[6] and with the list of CHI levels for SSCI journals (1985-2005)[7] (see description below). Due to considerable cleaning of raw Scopus data, this stage took about 80 working hours to complete.

Finally, information on patents granted to some of the researchers in the sample was retrieved using Google Patents (www.google.com) and Espacenet (www.ep.espacenet.com) databases, which contain comprehensive information on protected inventions and technical developments. Due to limited focus on patenting activity in this study, data collection was mostly limited to the titles of inventions and the dates when the patents were granted. Therefore, it did not turn out as time-consuming, resulting in total data collection effort for the project of about 150 working hours (4 working weeks).

3.3. Data analysis

As one can notice from the description above, the variety of the data collected was quite substantial, since I collected a number of descriptive demographic and career-related attributes as well as publication and patent lists with even more descriptive and numerical characteristics. Thus, before any analysis was possible, it was necessary to define for each person in the sample a set of variables which – when calculated and compared across different dimensions – could be potentially beneficial in shedding some light on the research questions. Overview of the variables used in the analysis presented in Table 2.

[6] Matching procedure succeeded for 95.8% of publications in 1999-2012, which seems high enough for including SNIP and SJR values in quantitative analysis.

[7] Matching procedure succeeded for 57.8% publications made by eight out of ten entrepreneurs. Even though not absolutely comprehensive, such a sample seems appropriate for testing Hypothesis 6 on the most general level.

Table 2. Overview of the variables used in analysis

Variable Group	Variable Name	Variable Description
Individual-related	Gender	Specifies person's gender and takes two values – male or female
	Age	Specifies person's age in the number of years from the year of birth and until 2014. Obtained for only 30 subjects in the sample.
	No. Years since PhD	Specifies the number of years from the year of obtaining a PhD and until 2014
	No. Employers	Specifies the number of distinct employers (organizations) a person worked for since obtaining a PhD
	Entrepreneurial Status	Specifies whether a person has been a founder (co-founder) of a commercial venture and takes two values – 0 (no) or 1 (yes). Obtained for all subjects in the sample based on publicly available and self-distributed information.
	FRS Status	Specifies whether a person is a member of the Royal Society of London for Improving Natural Knowledge and takes two values – 0 (no) or 1 (yes)
Productivity-related	No. Publications since PhD	Specifies the total number of publications (articles, articles in press, conference papers, letters, and notes) made by the person since the year of obtaining a PhD
	No. Publications per Year since PhD	Specifies the average yearly number of publications (articles, articles in press, conference papers, letters, and notes) made by the person from the year of obtaining a PhD and until the year of the last known publication

	No. Citations since PhD	Specifies the total number of citations received by the person since the year of obtaining a PhD
	No. Citations per Publication	Specifies the average number of citations received by one person's publication (since the year of obtaining PhD). Calculated in simple and weighted form with source's SNIP and SJR values (see below) as weights.
	No. Patents	Specifies the total number of distinct patents where the person is mentioned as an inventor
Bibliometric	No. Co-authors per Publication	Specifies the average number of co-authors per one person's publication (the subject herself is excluded from calculation)
	No. Distinct Co-authors	Specifies the total number of distinct (on the level of last name) co-authors included in bylines of person's publications (the subject herself is excluded from calculation)
	Source's SNIP	Specifies the average value of Source Normalized Impact per Paper (SNIP) for person's publications in 1999-2012. Individual SNIP values, derived from Journal Metrics database, measure contextual citation impact by weighting citations based on the total number of citations in a subject field.
	Source's SJR	Specifies the average value of SCImago Journal Rank (SJR) for person's publications in 1999-2012. Individual SJR values, derived from Journal Metrics database, measure scientific influence of scholarly journals that accounts for both the number of citations received by a journal and the importance or prestige of the journals where such citations come from.

	Position in Byline	Specifies the average position a person's name holds in the byline of a publication
	First Position Publications	Specifies the share of publications in which person's name holds the first position in the byline. Only publications with 1-10 co-authors are considered[8].
	Last Position Publications	Specifies the share of publications in which person's name holds the last position in the byline. Only publications with 2-10 co-authors are considered.
	Source's CHI level	Specifies source's classification group in continuum between basic research and applied technology and takes four values: 1 – applied technology; 2 – engineering science – technological science; 3 – applied research – targeted basic research; 4 – basic scientific research (Hamilton, 2003; Tijssen, 2010).

In analyzing the above variables, methods of descriptive statistics were mostly used. Specifically, the sample as a whole and sub-samples of entrepreneurs and non-entrepreneurs in particular were described and compared in terms of means and standard deviations. In addition, some elements of inferential statistics were included in the analysis when it came to measuring statistical significance of revealed differences between the sub-samples. The significance was checked in two ways, depending on the normality of variable's distribution, determined by Shapiro-Wilk test suitable for small samples (Shapiro and Wilk, 1965). For normally distributed variables, two-tailed t-test was applied (assuming equal or non-equal variances based on f-test value), while non-normal distributions were compared using Wilcoxon-Mann-Whitney test (WMW-test) (Mann and Whitney, 1947).

[8] Publications with 1-10 co-authors represent 93.8% of all publications. Publications with more co-authors are excluded from consideration to prevent distortion of results, since there are papers relating to major research projects with up to 220 different co-authors.

As a side note, it is also worthwhile to mention that due to sporadic (unstable) dynamics of publication activity for some subjects in the sample, comparisons based on time series were performed using smoothened trends by means of five-year moving averages.

4. Analysis

4.1. Personal and professional portrait of an academic entrepreneur

Answer to the first research question – "*What is a personal and professional portrait of an academic entrepreneur from the United Kingdom and what kind of ventures such entrepreneurs establish?*" – is provided through a three-fold analysis. First, individual entrepreneurs are compared to each other in order to establish a set of similarities in their demographic and professional characteristics. Second, in order to see what is specific to venture founders in the sample, they are collectively compared to their university colleagues who were not involved – to my knowledge – in any entrepreneurial activity. Finally, analysis of founded companies is performed to fill in remaining gaps and get a more comprehensive picture of academic entrepreneurship in the UK. Overall, this analysis establishes characteristics that are common for or unique to entrepreneurial researchers, sheds some light on the factors influencing their choices, and starts highlighting the link between commercial experience and individuals' scientific productivity.

Analysis of individual entrepreneurs

Analysis of demographic and career data of individual venture founders, employed by Cambridge in 2001, pictures an average entrepreneur as a dedicated male scientist of UK origin who studied at a top university and after many years of independent research for several different employers decided to combine his work in academia with commercialization of the most promising scientific findings. And although some of the studied dimensions possess a certain degree of variation, the above profile seems to correspond to the majority of entrepreneurs in the sample and quite accurately reflect their demographic qualities, educational background, and professional experience.

Starting with demographic characteristics, one can easily see absolute homophily in the sample when it comes to gender and a relatively high one regarding nationality. And while the prevalence of researchers-entrepreneurs from the United Kingdom seems natural due to methodological choices around data collection, the dominance of male entrepreneurs is in compliance with previous studies (e.g., Haeussler and Colyvas, 2011; Perkmann et al., 2013).

Educational background of university entrepreneurs from UK is also quite homogeneous. Six out of ten individuals got their undergraduate degrees and/or PhDs from the University of Cambridge or the University of Oxford which are considered top educational institutions within biosciences (as measured by The Complete University Guide, The Guardian University Guide, and The Sunday Times University Guide). Although this fact does not necessarily mean that they got better knowledge and skills, one may reasonably argue that they were exposed to the cutting-edge technologies while studying and were able to work with the most prominent researchers, thus increasing the likelihood of subsequent success in their own academic careers.

From a career perspective, all entrepreneurial individuals in the sample started their professional lives in academia after receiving a PhD and nine out of ten still hold professorship positions in universities, being in the state of "academic stasis" (O'Shea, Chugh, Allen, 2008). On the one hand, it may suggest that being entrepreneurial, these individuals perceive academia as complementary to their commercial endeavors, since it serves as a source for scientific findings that once established can be commercialized. On the other hand, it may also be a sign of them being less of entrepreneurs and more of researchers who just were persistent and enthusiastic enough to bring some of their scientific findings to the market. The latter explanation can also be supported by the fact that only two entrepreneurs had direct (employment-based) industry experience, while others did not explicitly work for any commercial organization (except their own ventures). Moreover, as again only two researchers were involved in more than one startup, entrepreneurial efforts of the individuals in the sample can hardly be a sign of deliberate switching from academia to industry.

Looking at professional mobility, one can infer from the sample that even though their careers are geographically limited to only one or two countries, spinoff creators are relatively mobile in terms of the number of different employers – eight out of ten individuals worked for four or more organizations. This might have a positive effect on their both scientific and commercial activities as they were more likely to expand their professional network and get access to additional knowledge as well as financial or other resources (Krabel and Mueller, 2005).

Finally, entrepreneurs from the sample seem quite similar when it comes to the timing of their venture activities. It took seven out of ten researchers 20 or even more years after getting a PhD to be able to start commercializing their scientific achievements, and only two individuals were fast enough to establish a startup within the first ten years of their academic careers. In other words, academic entrepreneurs from the UK either were reluctant to commercialization until something especially promising resulted from their efforts or were involved in a very complex scientific field with a long research cycle.

In summary, the above analysis suggests that entrepreneurs in the sample are successful university scientists who once channeled their diverse professional and prolonged scientific experience into economic value creation, while continuing working in academia.

Comparative analysis of entrepreneurs and non-entrepreneurs

When compared to their non-entrepreneurial colleagues, venture founders from the sample appear more experienced and more professionally mobile scientific "stars" (Rosen, 1981; Zucker, Darby and Brewer, 1998) who are able to consistently produce a significantly bigger amount of research findings of the same (or marginally higher) quality and, as a result, are highly respected in scientific circles. So it is mostly career-related and productivity data that contribute to this picture.

From a demographic perspective, two factors – gender and age – seem to differentiate university entrepreneurs from those without explicit history of independent commercial activities (referenced later also as non-entrepreneurs). While all spinoff founders are males, female researchers are actually present in non-entrepreneurial subsample, although their proportion is relatively minor (around 20%). Such a high prevalence of males in both subsamples might be potentially attributable to the nature of scientific field in question, which is generally more populated by male scientists (Haeussler and Colyvas, 2011), or to a certain gender bias in the data collected.

When it comes to age, entrepreneurial individuals seem to be on average almost five years older and significantly more homogenous as measured by standard deviation (Table 3). However, it must be noted that data on the year of birth were available for only five out of ten entrepreneurs and 25 out of 64 non-entrepreneurs, so they are by no means comprehensive. For this reason, age characteristic – useful for making inferences about person's experience – may be reflected by measuring the number of years since obtaining a PhD as a proxy, since this piece of data is present for everyone in the sample.

Table 3. Demographic and career-related comparisons

Variable	Entrepreneurs (n=10)		Non-Entrepreneurs (n=64)		WMW-test
	Mean	S.D.	Mean	S.D.	p-value
Age	63.4	7.7	58.6	12.5	0.452
No. Years since PhD	34.0	9.0	27.7	10.6	0.049
No. Employers	4.6	1.9	3.0	1.3	0.010

According to this indicator, entrepreneurs are more than six years more academically experienced and again notably less diverse than non-entrepreneurs. Moreover, the difference is statistically significant at 5% level as measured by Wilcoxon-Mann-Whitney test (chosen due to non-normality of the distribution). This fact supports a previously mentioned notion on the complexity of biosciences as a scientific field and significant amount of time and effort needed to come up with something truly commercializable. In addition, such a difference in experience may have implications on researchers' scientific productivity, which is going to be analyzed later on in this section.

Looking at career-related variables, one can easily spot a statistically significant difference in the average number of employers in a researcher's career, suggesting that entrepreneurs worked for 1.5 times more distinct organizations than did non-entrepreneurs (Table 3). Obviously, some part of this variation is attributable to the experience differences mentioned above, as entrepreneurial researchers just had slightly longer careers. However, given the magnitude of the figures and the fact that all but two entrepreneurs had four or more distinct employers, one could still argue in favor of a greater professional mobility of those who were involved in establishing their own companies. Moreover, this very fact may also be one of the factors explaining why these scientists were able to start their ventures in the first place. High mobility must have contributed to the size of their professional networks and might be essential in gaining access to additional knowledge as well as financial and other resources (Krabel and Mueller, 2005).

In addition to that, university entrepreneurs seem to be generally more successful and renowned than their non-entrepreneurial colleagues as half of venture founders are fellows of the highly prestigious Royal Society of London for Improving Natural Knowledge, while only 17% of non-entrepreneurs have been similarly acknowledged. This can be an additional factor explaining a better ability of some of the scientists to eventually commercialize their findings.

Another way to understand whether spinoff creators are better researchers is to investigate patterns of their scientific productivity and compare them with those of their non-entrepreneurial colleagues. Given the data collected, for each researcher in the sample it is possible to compute gross numbers of publications, citations, and patents, average number of publications per year as well as average numbers of citations per publication and patents per person (Table 4).

A relatively strong empirical evidence of the higher quantity and quality of the research performed by entrepreneurs can be noticed even at the highest analytical level. While venture founders represent only 13.5% of the sample, they account for 26.3% of all publications and 30.9% of all citations. In other words, as a group they seem to be considerably more productive and impactful. Given these data, it is of no surprise that on individual level an average academic entrepreneur from the UK, indeed, publishes more than two times more papers and receives almost three times more citations during his career than does his colleague without any founding experience (Table 4). The differences are significant at 1% level as measured by Wilcoxon-Mann-Whitney test for non-normal distributions.

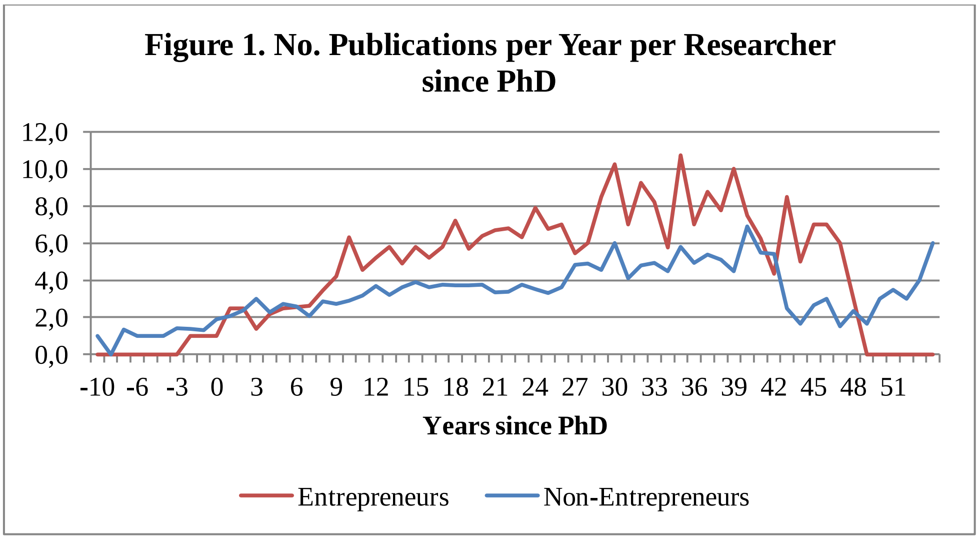
Table 4. Productivity-related comparisons

Variable	Entrepreneurs (n=10)		Non-Entrepreneurs (n=64)		WMW-test p-value
	Mean	S.D.	Mean	S.D.	
Publications					
No. Publications since PhD	177.0	98.0	78.3	57.2	0.001
No. Publications per Year since PhD	5.1	2.0	2.9	1.8	0.001
No. Citations	9,725	8,652	3,478	3,290	0.004
No. Citations per Publication	50.3	33.9	45.7	32.7	0.512
No. Citations per Publication (weighted by SNIP)	78.9	59.1	76.2	79.4	0.398
No. Citations per Publication (weighted by SJR)	76.7	47.3	73.8	56.5	0.596
Source's SNIP	1.58	0.4	1.61	0.5	0.675
Source's SJR	3.17	1.7	3.10	1.6	0.782
Patents					
No. Patents (all subjects)	5.9	3.7	0.2	0.7	0.000
No. Patents (those with patents)	6.6	3.3	1.7	1.1	0.003

Although insightful, these numbers, however, should be treated carefully. On the one hand, lifetime productivity is obviously dependent on the duration of one's career and entrepreneurial individuals from the sample seem to be slightly more experienced as argued above. On the other hand, gross citation figures – and, therefore, inferences about quality of research – may be distorted simply because of the higher total number of publications relevant for entrepreneurs. In other words, one needs to control for at least few variables to make a more confident conclusions on scientific productivity of both groups.

When duration of one's career is controlled by calculating the average number of publications per year since PhD (and until the year of the last publication), entrepreneurs still seem to possess a statistically significant advantage, although their dominance over non-entrepreneurs is slightly reduced to 1.75 times more papers per year (Table 4). Importantly enough, these figures are not influenced by radical outliers as all but one entrepreneur exceed the non-entrepreneurial average for yearly publications.

Moreover, consistently higher publishing activity of venture founders can be spotted when plotting average number of publications per year per researcher against time. Using number of years since PhD as a time series – which is also useful in controlling for differences in experience – Figure 1 clearly demonstrates that entrepreneurs from the sample start being more scientifically productive than non-entrepreneurs in just a few years after commencing a formal academic career and remain so almost to the very end of a professional live.



Finally, analysis of patenting activity reveals a strong superiority of entrepreneurs. While there are only 14% of patent holders among non-entrepreneurs, nine out of ten venture founders have secured their intellectual property rights at least once. In addition, when only those with patents are considered, entrepreneurs possess almost four times more patents on average and the difference is statistically significant at 1% level (Table 4). This seems, however, natural. Establishing proper intellectual property rights is a basic requirement for long-term commercial value creation and is an expected move for those who decided to bring their research outcomes to the market. In addition, external validation of a scientific discovery by means of a patent may also be at least indirectly related to high quality of research.

All in all, these data suggest that when it comes to the quantity of research as proxied by publication and patent figures, entrepreneurial individuals demonstrate consistently higher scientific productivity then those without commercial experience.

With regard to potential quality of scientific efforts, citation patterns and journal-specific metrics can be considered. Although entrepreneurs seem to have slightly more citations per publication (Table 4), it might be attributable to a really renowned outlier whose citation rate is more than three times higher than the average for non-entrepreneurs. When such outliers are excluded from both groups, citation rates for entrepreneurs and non-entrepreneurs are reduced to 40.7 and 37.1 citations per publication respectively. However, in both cases the differences are not statistically significant, which prevents any further generalizations.

A more refined analysis of research quality is possible when prestige and impactfulness of a source journal are taken into account, since one can argue that the findings published, for example, in *Nature* should be of a higher scientific value than those mentioned in a local and significantly less known journal. When average citations rates for the period from 1999 to 2012 are calculated using SNIP and SJR values, discussed in Methodology, as weights, again entrepreneurs' papers are cited slightly more often (Table 4), but the difference is relatively marginal and insignificant.

And this result actually makes sense, because when the groups are compared by the average SNIP and SJR of the sources they chose for publication from 1999 to 2012, there are no statistically significant differences (Table 4). Both entrepreneurs and non-entrepreneurs chose journals of the same level of prestige and impactfulness to report their findings, meaning that there is no evidence to suggest that one of the groups produces a scientific product of better quality. If it was the case, one would expect to see significantly higher SNIP or SJR values for this group's sources.

Summarizing proxies of research quality, one can argue that there are no considerable differences in the impactfulness of an average scientific product created by university entrepreneurs and those who have no founding experience. However, consistently higher publishing and patenting activities of the entrepreneurial group may still be considered as indirect evidence in favor of better quality of their research. Although on average their findings may be comparable with those of the opposing group, venture founders seem to be able to come up with them – and even make them proprietary – considerably more often.

Analysis of entrepreneurial ventures

Data collected on ten university entrepreneurs from the sample show that they were involved in establishing at least 12 commercial companies (Table 5). An average venture can be pictured as a relatively small yet commercially successful biotechnology firm which represents a university spinoff established by a couple of scientists, financed by venture capital, and either active today or acquired after few years of operation.

Looking at the type of business relevant for these companies, one can see from Table 5 that all ventures directly relate to biotechnology and perform research, development, and at least initial production in drug discovery (five firms), general medicine (three firms), agriculture (two firms), and general biochemistry (two firms) subfields of the biotechnological industry. In other words, all companies seem to be involved in direct commercialization of scientific findings of their founders and employees and are not limited to selling knowledge by providing only consulting services. However, given their relatively small size, objective absence of huge financial resources, and relatively high capital intensity of the industry, most of the ventures – especially within drug discovery – partner with leading players (e.g., top pharmaceutical companies) to be able to reach a bigger scale and bring new products to the market. And it is consistent with previous research science-industry collaboration in biotechnology (Powell and Owen-Smith, 1998).

Table 5. Overview of the companies established by academic entrepreneurs

Type of Activity	Year of Foundation	No. Founders	No. Investors	Current status	Year(s) of Acquisition
Medicine-related biotechnology	1998	2	1	Acquired	2003 2009
Drug discovery	1989	N/D	N/D	N/D	–
Drug discovery	1999	3	N/D	Acquired	2011 2013
Drug discovery	1996	2	N/D	Dissolved	–
Medicine-related biotechnology	1999	2	1	Active	–
Medicine-related biotechnology	1996	6	5	Acquired	1998
Agricultural biotechnology	2008	N/D	N/D	N/D	–
Drug discovery	1997	1	7	Acquired	2006
Drug discovery	2011	4	4	Active	–
Agricultural biotechnology	2012	1	N/D	Active	–
General biochemistry	2004	2	2	N/D	–
General biochemistry	2003	2	3	Active	–

Interestingly enough, in most cases, establishment of these ventures was a collective effort of at least two founders. On the one hand, it is a sign of collaborative culture of either UK universities or biosciences in general. On the other hand, it may also be attributable to the complexity of the field in question, which requires significant intellectual inputs from a team of several dedicated researchers. Another important similarity, spotted for at least eight out of 12 ventures, is the background of the founders who come exclusively from academia. In other words, most of the companies are direct university spinoffs and have had limited exposure to the industry (at least at the level of founders). This is, again, indicative of the fact that it is researchers' academic experience that becomes a source of their commercial activities and it is their scientific findings that are being marketed.

When it comes to financing, one can argue that in the majority of cases spinoffs creators were able to attract external investments as seven out of 12 companies were backed by one or usually a group of venture capitalists. This is, however, not a surprise given high uncertainty and capital intensity of biotechnology. In addition, having experience in applying for grants within academia, entrepreneurial researches might be also as good in using their competences to persuade investors.

Finally, university entrepreneurs from the UK seem to be generally successful in their commercial activities. While at least three firms are still active today, four ventures have been acquired by bigger players after few years of operation, and there is information about only one dissolved company. This is in line with existing literature, explored earlier in the thesis, and provides additional evidence in favor of the "star" status of venture founders who are not only extraordinary researchers but also able entrepreneurs.

Summary on the first research question

Overall, analysis developed in this section and related to the first research question suggests a relatively clear pattern of university entrepreneurs from the UK being more experienced, more professionally mobile, and – importantly enough – significantly more scientifically productive, especially when it comes to the quantity of the research produced. In other words, they can be considered scientific "stars" (Zucker, Darby and Brewer, 1998) that are able to succeed in both academia and industry. Thus, it is now time to see what factors and to what extent may correlate with such a finding.

4.2. Academic entrepreneurship and scientific productivity

Analysis relating to the first research question suggests a positive relationship between researcher's involvement in entrepreneurship and his scientific productivity, measured by the number of peer-reviewed publications and patents. Indeed, academic entrepreneurs from the UK seem to be highly successful and renowned scientists with an ability to produce research findings in considerably higher quantities, when compared to those without business experience.

At the same time, this apparent relationship should be treated carefully since correlation does not justify causation. In general, such a link may be a result of either productivity gains achievable by researchers once they become venture founders or some additional factors that positively correlate with both studied phenomena. Hypotheses formulated in Theoretical foundation are aimed at testing both options, thus providing sufficient guidance for answering the second research question.

Scientific productivity around and after venture creation

Although data collected does not allow for comprehensive investigation of the direct link from researchers' entrepreneurial experience to changes in scientific productivity, Hypotheses 1a, 1b, and 5 can still be relatively easily tested by investigating dynamics of one's publication activity around and just after the time of spinoff creation.

Analysis of time series presented below delivers mixed results, providing no clear evidence in favor of either Hypothesis 1a or Hypothesis 1b. On the one hand, five out of ten entrepreneurs, indeed, demonstrate significant positive changes in five-year moving average for the number of publications per year during a five-year period after starting a company, while two more founders show marginal improvements (Figure 2). On the other hand, these dynamics may also be attributable to the factors of time and researchers' experience, since overall scientific productivity is consistently growing in time (Figure 3) and scientists tend to publish more each year until a specific point in their careers (Figure 4).

Therefore, one may want to compare the above developments against long-term tendency that is likely to accumulate all covariates but entrepreneurship. Results of this analysis, presented on Figure 5, show neither consistent improvements above nor consistent reductions below the trend line for the majority of entrepreneurs. Three venture founders seem to become more productive, other three lowered publication activity, while the rest performed according to the trend. Thus, neither Hypothesis 1a nor Hypothesis 1b find support in the data collected, suggesting that the direct influence of entrepreneurial experience on one's scientific productivity may be absent or mixed.

Therefore, there may be some other factors behind positive correlation between the two phenomena.

Figure 2. Five-Year Moving Average for No. Publications per Year after Establishing a Company

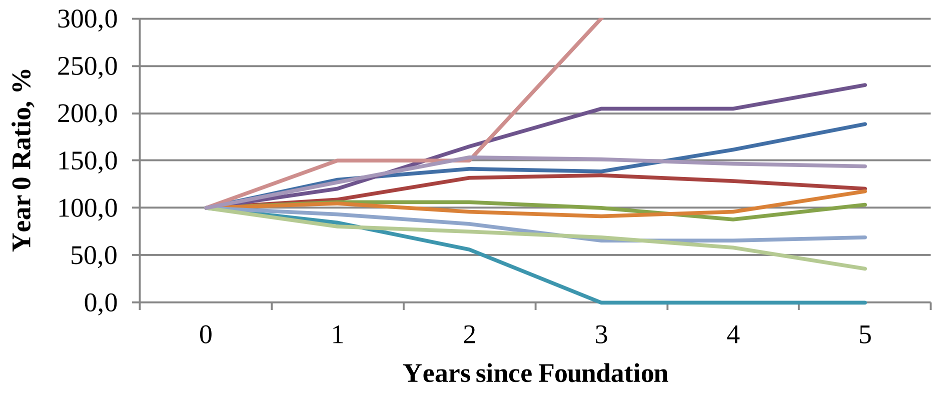


Figure 3. Publications per Researcher across Time

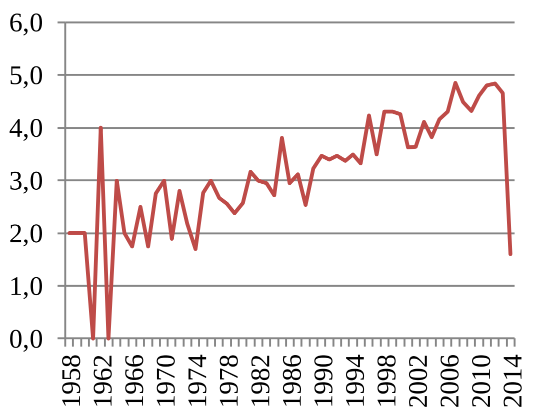
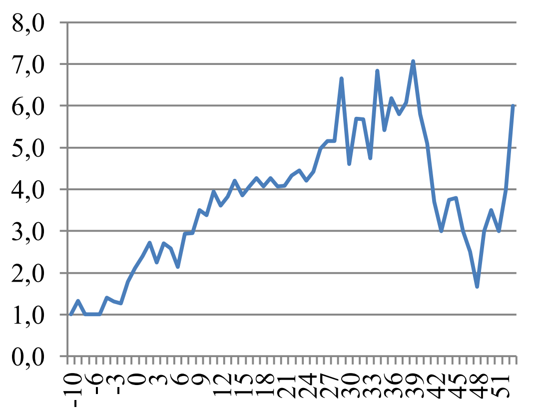
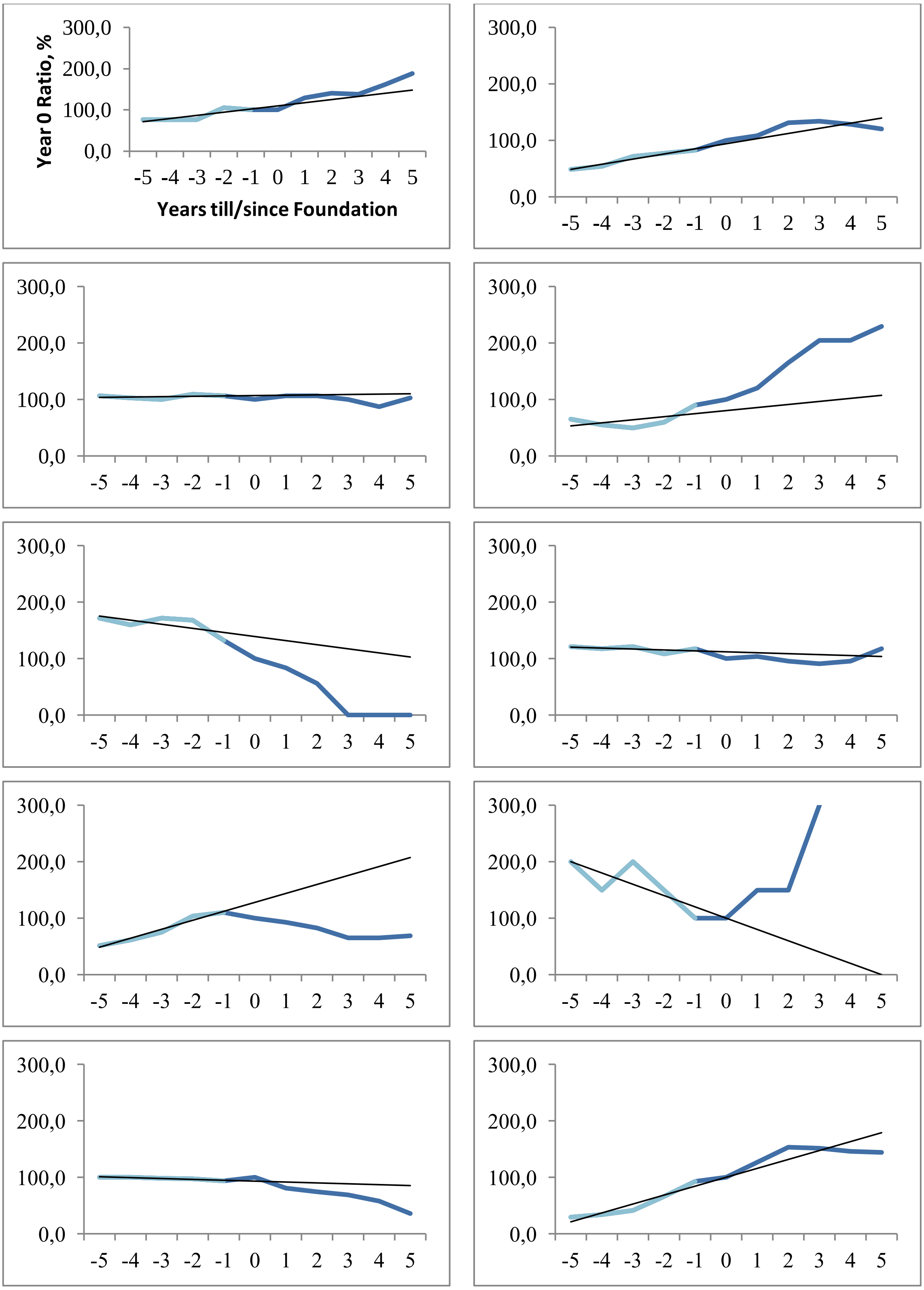


Figure 4. Publications per Researcher vs. Years since PhD



As for Hypothesis 5, regarding the research slowdown around the time of venture creation, Figure 5 does not seem to provide strong supporting evidence either. Only two entrepreneurs demonstrate a relatively marginal slowdown during the period from the one year before foundation to the one year after it. Thus, academic performance of university entrepreneurs from the sample did not seem to suffer from the secrecy problem associated with the slowdown argument.

Figure 5. Five-Year Moving Average for No. Publications per Year against Trend before Foundation



Note: Trend line is based on data for five years before foundation

Professional network

An average university researcher seems to have two interrelated and mutually reinforcing ways to expand her professional network. On the one hand, scientists are likely to be involved in inter-organizational cooperation with researchers from other universities, companies, and governmental institutions, while sticking to their initial employers. On the other hand, they can exercise professional mobility and switch among workplaces in different organizations within and outside academia. In both cases, the size of their professional network is likely to increase, as is their access to new ideas, knowledge, financial and other resources. This, in turn, may have a positive influence on both entrepreneurial inclination and scientific productivity (Hypothesis 2), as was discussed in Theoretical foundation.

Data collected on university researchers from the UK suggest that entrepreneurial individuals seem to possess significantly larger professional networks than their non-entrepreneurial colleagues. As was described earlier (see Table 4), there is a more than 1.5-times difference in the number of distinct employers that representatives of both groups worked for throughout their careers. Obviously, some part of this difference is simply a consequence of entrepreneurs mentioning ventures among their workplaces. However, it does not explain everything, since not every founder in the sample considered his company as another job. Thus, entrepreneurs, indeed, seem to be more professionally mobile and this may positively influence their publishing activity as there is a moderate correlation between the number of different employers and both the total number of publications and the average number of publications per year since PhD (Table 6).

Another argument in favor of Hypothesis 2 is apparent when the number of distinct co-authors that each researcher collaborated with throughout her academic career is taken into account. Entrepreneurs on average have more than 2.5 times more distinct co-authors (272.7 vs. 106.0; WMW-test p-value < 0.001) and nine out of ten exceed the average level for non-entrepreneurs. In other words, UK university entrepreneurs tend to work with significantly more diverse cooperation base and can, therefore, leverage these numerous contacts to produce additional research findings or resources, which would be unlikely without those links. In addition, there is a strong correlation between the number of distinct co-authors and both indicators of publication activity (Table 6), suggesting that this factor positively correlates with both academic entrepreneurship and scientific productivity.

Table 6. Relationship between different variables and publication activity

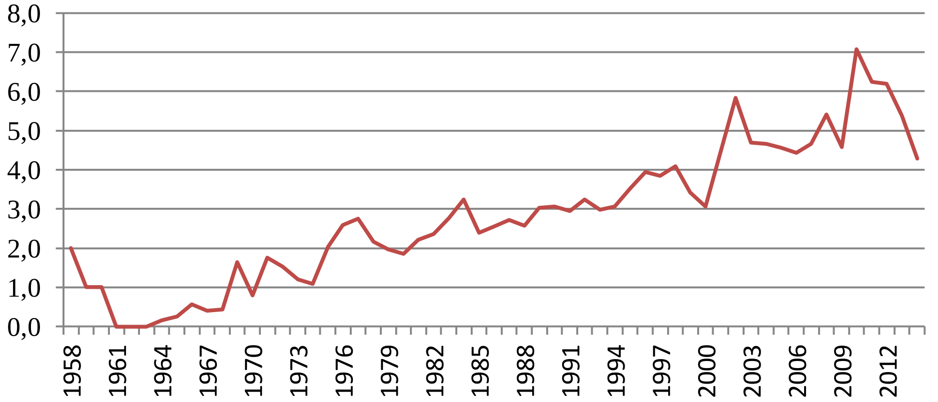
Variable	Pearson correlation coefficient	
	No. Publications since PhD	No. Publications per Year since PhD
No. Employers	0.46	0.35
No. Distinct Co-authors	0.88	0.72
No. Co-authors (total)	0.88	0.69
No. Co-authors per Publication	–0.02	–0.05
Last Position Publications (share)	0.39	0.38
Position in Byline	0.27	0.24

Overall, Hypothesis 2 is supported by the data collected and, indeed, university entrepreneurs from the UK seem to possess larger professional networks than their non-entrepreneurial colleagues, while the size of one's network is positively linked to publication activity.

Research team size

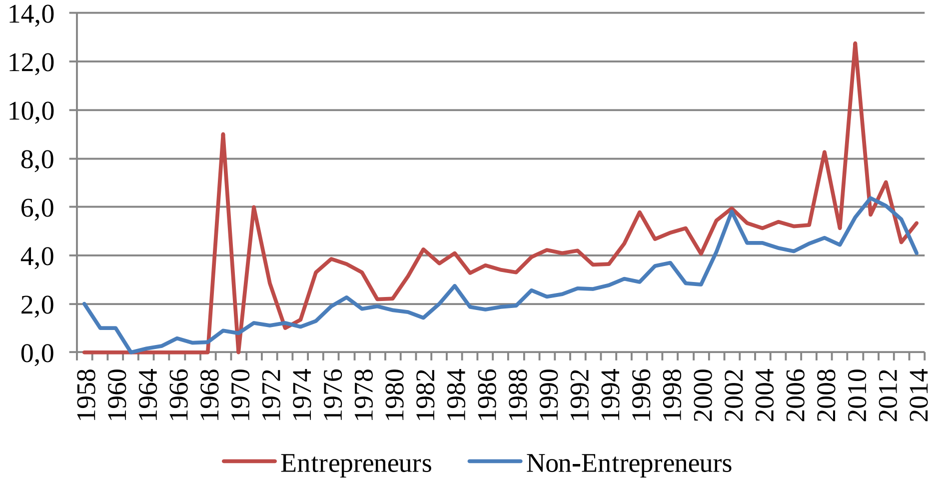
Evidence from the literature suggests that modern science is a product of collective efforts and research cooperation is now higher than ever before (Adams, Black, Clemmons and Stephan, 2005; Wuchty, Jones and Uzzi, 2007). In the data collected, this tendency can be demonstrated on a publication level by the number of co-authors per publication that is consistently growing in the last decades (Figure 6). It means that contemporary scientific endeavors – especially in such a complex field as biotechnology – require bigger teams with complementary knowledge and skills. In addition, existing literature comes up with a logical argument that a bigger team is more likely to find something valuable faster than a lonely researcher or just a couple of them. In other words, the size of the team, reflected, for example, in the number of co-authors per publication may have an influence on scientific productivity (Hypothesis 3).

Figure 6. No. Co-Authors per Publication across Time (all subjects)



When academic entrepreneurs and their non-entrepreneurial colleagues from the sample are compared by this factor, the conclusion is quite clear – venture founders tend to work in slightly bigger teams and do that consistently across time. Calculations show that an average entrepreneur has almost 15% more co-authors per publication (4.7 vs. 4.2; WMW-test p-value = 0.038) and seven out of ten founders exceed the average value for non-entrepreneurs, thus validating the finding even further. Moreover, working in bigger teams seems to be a strategic choice for entrepreneurial individuals and not a coincidence, since one can observe a clear difference between two groups for almost 40 years (Figure 7).

Figure 7. No. Co-Authors per Publication across Time



The link between team size and scientific productivity is, however, not as clear. While gross number of co-authors is strongly and positively correlated with publication activity, average number of co-authors per publication does not seem to have any relationship with scientific productivity (Table 6).

All in all, the above evidence supports Hypothesis 3, meaning that academic entrepreneurs from the sample conduct research in slightly bigger teams. But whether it may also be the factor of their higher publication activity is not derivable from the data collected.

Artificial mentioning

As mentioned earlier, there may exist some factors which are likely to inflate one's scientific productivity beyond its natural level. More specifically, when using publication and citation rates as a measure of research output, one should be aware of artificial mentioning, which is a situation when a researcher is included in the byline not due to her significant contribution but because of reputational or status-related factors (Hypothesis 4).

Calculations aimed at testing this hypothesis in relation to university entrepreneurs from the UK seem to provide at least moderate support (Table 7). First, while almost every third publication carries non-entrepreneur's name at the first position in the byline, only 10% of publications do the same for entrepreneurs, suggesting a relatively small contribution from venture founders. Second, entrepreneur's name is 23% more likely to be the last one among co-authors, which seems to be a direct consequence of their seniority and high position in organizational hierarchy. Finally, an average venture founder usually holds fourth (3.9) position in the byline, while a typical non-entrepreneurial researcher is usually number three (2.9). Given statistical significance of the above differences, it seems that venture founders are not the ones who contribute the most to the publication in question, but they are still mentioned as co-authors potentially because of their formal status or reputation.

Analysis of the same indicators but against one's publication activity reveals moderate positive correlations between the share of last position publications (as well as average position in byline) and performance indicators (Table 6), suggesting that those who are mentioned towards the end of the list are generally more scientifically productive.

Table 7. Byline position indicators

Variable	Entrepreneurs (n=10)		Non-Entrepreneurs (n=64)		Difference -test p-value
	Mean	S.D.	Mean	S.D.	
Position in Byline	3.9	0.4	2.9	0.9	0.000[b]
Position in Byline (weighted by the number of co-authors)	4.8	0.5	3.6	1.1	0.000[b]
First Position Publications (share)	0.10	0.0	0.30	0.2	0.001[c]
Last position Publications (share)	0.56	0.1	0.43	0.2	0.022[a]

Note: a – two-tailed t-test assuming equal variances; b – two-tailed t-test assuming unequal variances; c – Wilcoxon-Mann-Whitney test for non-normal distributions.

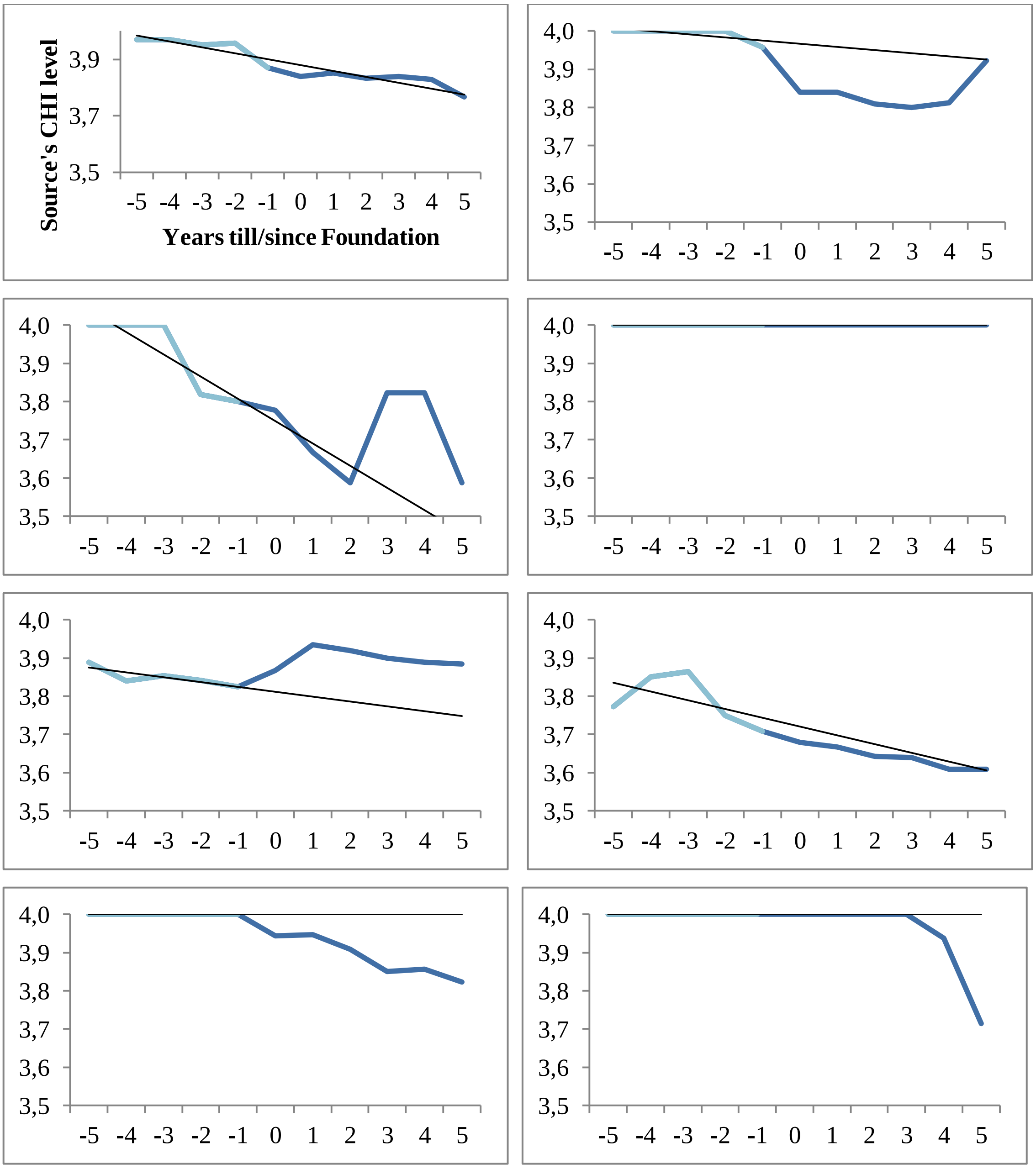
Together with the fact that entrepreneurs are much more likely to be renowned fellows of the Royal Society, the above evidence supports Hypothesis 4 and, indeed, scientific productivity of venture founders from the UK may be partially inflated by artificial mentioning.

Skewing problem

As for Hypothesis 6, it relates to the concern expressed in the literature that establishing a venture may force an academic to shift the nature of her research towards more applied topics, which would be more suitable for appropriation of economic value behind the company (Van Looy, 2004; Gulbrandsen and Smeby, 2005). In terms of the data collected, such a shift may be spotted when looking at the journals chosen for publication and their relative position within the continuum between applied and basic research, measured by one of four distinct CHI levels, described in Methodology. Thus, if the skewing problem exists in the sample, one should expect to see lower average CHI levels around and just after the time of spinoff creation.

Empirical data presented in Figure 8, however, do not provide sufficient evidence in favor of Hypothesis 6.

Figure 8. Five-Year Moving Average for Source's CHI Levels against Trend before Foundation



Even though two out of eight entrepreneurs with available data demonstrate relatively steep decline in average source's CHI level, the magnitude of these changes across chosen 10-year period does not, in general, exceed 10%. This means that academics continue to choose journals on basic or targeted basic research after creating a company. In addition, there seem to be a shared tendency towards more applied research with time, which, again, rather contradicts than supports the hypothesis.

Based on these figures, one can conclude that skewing problem is not apparent in the sample collected, and the nature of entrepreneurs' publication activity does not seem to change significantly either prior or after establishing a spinoff.

Summary on the second research question

Overall, the analysis relating to the second research question provides some insights into the nature of positive relationship between academic entrepreneurship and scientific productivity. While entrepreneurial experience in itself seem to be neither necessarily beneficial nor necessarily adversarial to researchers' scientific productivity, there are such factors as larger professional networks, bigger research teams, and artificial mentioning, which correlate with both entrepreneurial status and publication activity, thus potentially contributing to the positive relationship between the two.

5. Discussion and conclusions

The Triple Helix model of a university-industry-government relations, formed as a consequence of recent political, economical, and social changes and increasingly encouraged in Western societies today, considers entrepreneurial objectives an integral part of university's mission. Thus, it urges for more intense commercialization of research results and spinoff activities among faculty members, leading to emergence and subsequent development of academic entrepreneurship around the world.

Being an important channel of knowledge and technology transfer, this phenomenon, however, may be fraught with risks of decreased scientific performance, as research and commercialization are now supposed to compete for person's time and resources. Therefore, relationship between academic entrepreneurship and scientific productivity constitutes an important and fruitful research area that would help us better understand how to make universities both more scientifically advanced and commercially innovative.

In the present thesis, this relationship was studied through extensive data collection and subsequent quantitative analysis. Focusing on biosciences and UK universities as the main object of study, the study established personal and professional portrait of an academic entrepreneur and investigated the existence and possible explanations of the link between venture founding and publication activity. The most important research findings, as they relate to the research questions specified in Introduction, can be summarized as follows:

1. Academic entrepreneurs from the United Kingdom are mostly very productive and renowned scientific “stars” of male gender with a few additional years of academic experience and higher professional mobility, when compared to non-entrepreneurial colleagues.
2. Ventures founded by academics from the sample tend to be direct university spinoffs that belong to biotechnological industry and are either still active or acquired, i.e. relatively successful.
3. There found a positive correlation between researcher’s entrepreneurial status and the quantity of his scientific output measured by publication activity and patenting.
4. While commercialization itself has not been found necessarily beneficial to productivity, larger professional networks, bigger teams, and artificial mentioning of researchers turned out to be positively correlated with both entrepreneurship and higher publication activity.

Interpretation of research findings

When it comes to the first research question, the above findings (the first two points) seem to be in line with the existing research, thus providing external validation for prior studies. For example, as do those of Klofsten and Jones-Evans (2000) or Haeussler and Colyvas (2011), my analysis shows considerable gender inequalities in academic entrepreneurship, as data collection failed to find any female founders to be included in the sample. Two potential explanations come to mind. On the one hand, it is possible that although existent, businesswomen have not been spotted and fallen out of my attention, given a relatively small subset of only ten entrepreneurs. On the other hand and apart from a potential bias, it is generally accepted that some scientific areas are inherently male-based (Haeussler and Colyvas, 2011), males are more inclined to venture founding (Hipple, 2010), and academic entrepreneurship is a relatively rare phenomenon by itself (Perkmann et al., 2013). Thus, it is plausible that a major part of academic entrepreneurship in this area is, indeed, represented by male scientists, given that there were only 20% of female researchers doing biosciences at Cambridge in 2001.

The fact that venture founders from UK tend to be older and more academically experienced is also in compliance with, for example, Stephan et al. (2007) and Perkmann et al. (2013). Rationale behind such a finding relates to accumulation of additional intellectual (human) capital with time. It, in turn, is likely to increase entrepreneurial capacity (Clarysse, Tartari and Salter, 2011) of an academic, helping her better recognize promising market opportunities for her scientific outcomes. A similar interpretation seems also plausible for the higher professional mobility of entrepreneurs. In this case, working for different employers in different environments and with different people not only improves one's intellectual capital (by exposing an individual to various situations and issues) but also social capital, i.e. the network of professional contacts, which may then be used to spot lucrative market ideas or get access to resources necessary for creating a venture (Stam, Arzlanian and Elfring, 2014).

Finally, large differences in scientific productivity between academic entrepreneurs and their non-entrepreneurial colleagues support the opinion that it is the most bright and successful faculty members who are likely to establish their own companies, while continuing working in academia (Perkmann et al., 2013). On the one hand, important scientific discoveries in biotechnology, made by the most able researchers, are likely to have high business potential. One the other hand, those academics who are able to shorten research cycle and deliver valuable findings more often would just have a larger portfolio of marketable ideas to choose from. In addition, high reputation in scientific world, which is to a great extent a function of one's productivity, may become critical in attracting investors and channeling an idea into an operational business.

While this point already presents a positive link between academic entrepreneurship and scientific productivity and, therefore, validates previous work (e.g., Van Looy et al., 2004; Haeussler and Colyvas, 2011), it is the hypotheses tested in relation to the second research questions that provide a more fine-grained picture. In general, such a link may be a result of either productivity gains achievable by researchers once they become venture founders or some additional factors that positively correlate with both studied phenomena. According to my analysis, it is rather the latter that sheds some light on the direction and reasoning behind the established relationship.

Analysis of entrepreneurs' productivity just before and after venture creation turned out to show mixed results, as some academics demonstrated improvements, while others either continued according to the trend line or slightly reduced publication activity. In other words, entrepreneurial experience itself does not appear to have a clear positive or negative effect on productivity of venture founders. Neither it seems to provide studied researchers with something special that would then be channeled into more publications (e.g., funds or research freedom), nor causes it distinguishable delays or substitution effects for faculty members from the sample. Alternatively, these issues may just balance each other. As such, this finding provides support for rather compatibility of high scientific productivity and academic entrepreneurship than for their antagonism.

In addition, it implies that the positive correlation established between two phenomena may be attributable to something that happens before one decides to become a founder. My analysis reveals at least three candidates for such a role. First, the size of researchers' professional network (proxied by distinct co-authors and employers) has been found to be associated with both higher productivity and spinoff creation, which is in line with arguments developed by Bekkers and Bodas Freitas (2008) and Bozeman, Fay and Slade (2013). Interpreting this result, one may again refer to accumulation of social capital and improvements in absorptive capacity. On the one hand, knowledge and resources of different people a researcher knows may be used to deliver valuable scientific discoveries and get them published in the most prestigious journals. On the other hand, the same contacts are likely to be of great value, when spotting, pursuing, and exploiting promising market opportunities. To put in differently, in the beginning professional network may reinforce publication activity of an academic, while later on it becomes also conducive for spinoff creation, thus making the two correlated.

Second related factor is the average size of research team (measured by the number of co-authors for a single publication), which is found to be higher for entrepreneurs and seemingly correlated with productivity figures. Although both science and business are based on collective efforts, it might be that venture creation requires bigger teams of specialized individuals and my analysis shows that it is rare that the company is established by a lonely inventor. This bigger team size, in turn, is logically beneficial for more complex and, probably, valuable projects or just makes research cycle faster, thus allowing for more scientific output per unit of time. All in all, the finding is consistent with the existing literature (e.g., Haeussler and Colyvas, 2011) and may partially explain correlation between academic entrepreneurship and productivity.

Finally, artificial mentioning seem contributing to the picture. My analysis shows that in contrast to those of non-entrepreneurs, names of spinoff creators are more likely to be put at the end of article's byline than in the beginning, which follows the pattern usually observed for honorary or senior faculty members (Bates et al., 2004; Lissoni, Montobbio and Zirulia, 2013). This may be a sign that entrepreneurial individuals are not the ones whose contribution to the publication is the most significant, but they still become co-authors because of their reputation or position in organizational hierarchy. In other words, publication activity of academic entrepreneurs from the UK may be to some extent inflated by artificial mentioning, making venture founders seemingly more productive.

All in all, the above discussion points to a conclusion that academic entrepreneurship and scientific productivity go hand in hand, and while there may not necessarily be any productivity gains associated with founding a venture, no negative tradeoffs are also present, according to the analysis performed earlier in the thesis.

Limitations

Although shedding some light on the research questions specified in Introduction, this analysis is not without limitations, most of which stem from data collection performed. First, analytical sample used in the study may be subject to at least two biases. On the one hand, I was not able to spot any female entrepreneurs and overall presence of female researchers in the sample may not be fully representative of UK universities in particular and university science as a whole. On the other hand, my data collection was based either on publicly available information or on data provided by subjects themselves. Thus, a significant part of the sample may contain either very open faculty members who like to share information about themselves or those who are successful and renowned enough to be mentioned in publicly available sources. In any case, it may compromise representativeness of the sample with regard to general population.

Second set of limitations comes from certain methodological choices. Having strategically delimited scientific inquiry to the United Kingdom and departments related to biotechnology, I obviously reduced potential external validity of research findings and had to work with a relatively small sample. This means that although valid for biotechnology researchers worked for Cambridge in 2001, my conclusions might not be fully generalizable to all universities and scientific areas. However, given that most of the findings support previous studies, this limitation does not seem to have severe implications. Nevertheless, similar analysis performed in relation to other higher education institutions and industries is beneficial and can only be encouraged.

Finally, at least one limitation comes from data analysis. Relying mostly on descriptive statistics and using only minor elements of inferential one, this thesis captures most important and distinguishable findings but does not provide a picture in which all – or at least a number – of revealed factors were studied together. In other words, regression analysis could become complementary to descriptive statistics in producing a more fine-grained picture of relationship between academic entrepreneurship and scientific productivity.

A good candidate for such an analysis – given the nature of the data collected – is survival analysis prevalently used in economics, engineering, and medical trials. With regard to academic entrepreneurship, it may be helpful in quantifying influence of different factors on the likelihood of a faculty member becoming a venture founder. For example, a Cox proportional hazards model that contains variables related to publication activity, professional network, team size, and artificial mentioning could show statistical significance of each explanatory factor – thus either validating or rejecting above findings – and their relative impact on the dependent variable, i.e. establishing a spinoff by an academic. Thus, it constitutes one of the fruitful avenues for further research.

Contributions and implications

Despite the above limitations, this thesis seems to provide a few contributions to the existing literature. First, it increases the amount of empirical knowledge on academic entrepreneurship, thus providing more food for thought and helping better understand complex interplay between spinoff creation and scientific productivity.

Second, it offers a number of fresh perspectives. For example, my analysis uses variables such as the number of distinct co-authors and author's position in byline, which are rarely considered in the literature on academic entrepreneurship. As a result, it expands methodological portfolio available for researchers and adds a few theoretical perspectives into consideration. In addition, the present study investigates not only naturally justifiable explanations for the link between commercialization and scientific productivity, but also includes non-natural factors such as artificial mentioning, which is again not so widespread in the existing research and makes it a little bit more comprehensive.

Third, this work serves as external validation for some prior studies (e.g., Van Looy et al., 2004; Haeussler and Colyvas, 2011; Bozeman, Fay and Slade, 2013), thus helping the field move towards consensus. Specifically, it argues for positive correlation between venture founding and university research and links the relationship to wider professional networks and bigger teams that academic entrepreneurs seem to possess.

Finally, my research also implies a few practical implications for policy makers, investors, and academics thinking of becoming entrepreneurial. First and foremost, given that no negative tradeoffs associated with academic entrepreneurship were found, one may urge for further promotion of the Triple Helix model by higher education officials. In the absence of distinguishable drawbacks, intensified commercialization by faculty members is likely to contribute to innovation, knowledge transfer, and general economy, while maintaining – and in the best case scenario even increasing – scientific output.

Second, to be more effective, these promotion efforts should target more experienced, mobile, and at the same time highly productive individuals. My analysis shows that it is them who are more likely to be interested in venture creation in the first place. Thus, by shifting attention from academics in general to this specific group of faculty members, higher education officials could improve conversion rates associated with their campaigns, while limiting waste of resources.

Third, spinoff creation may be indirectly supported by university staff through facilitating more opportunities for inter-organizational collaboration among academics. Given that such interactions expand one's professional network and the size of this network is positively associated with both commercialization and scientific performance, advances in social capital of faculty members become a win-win situation for all stakeholders and could only be encouraged.

Fourth, venture capitalists looking for promising ideas and technologies should more closely follow work of scientific stars and actively approach them with commercialization proposals. On the one hand, highly productive researchers are found to be more inclined to start commercialization at later stages of their careers. On the other hand, they are also more likely to have broader portfolios of potentially valuable findings. Such a combination is a good way for venture investors to improve odds of supporting a truly profitable business promising a higher payoff.

Finally, it seems beneficial for academics with commercial ambitions to actively build a broader professional network and try to work in bigger research teams. As shown above, it not only positively correlates with scientific productivity but also may lead to a higher probability of business success.

Once implemented in practice, these suggestions are likely to create a reinforcing loop, making academic entrepreneurship a more widespread phenomenon and, therefore, contributing to economic well-being of nations all over the world.

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Appendix – Tables and figures

Tables

Figures