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Commercialization of Emerging Technology: The Role of Academic Entrepreneur

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Abstract

This paper explores the role of academic entrepreneur in the commercialization of emerging techno-creative innovations. The discussion is focused on nanotechnology. Universities commonly known as the source of technological innovation play an important role in transferring university-invented technology and expertise to the market. With sufficient and supportive infrastructure for technology transfer in place, academic entrepreneurs may form start-up companies and make profits based on intellectual property generated from these innovations. It is believed that for successful new technology venture, entrepreneurs should possess a combination of different skill sets to face challenges in various stages of commercialization process. Therefore, this paper reviews to what extent academic researchers are the right translators of novel science-based technology in bringing innovations from lab to market, hence the role of academic entrepreneur. Analysis is performed based on case studies and publications pertaining to learning experiences of successful technology start-ups in developed countries. Subsequent analysis suggests that entrepreneurship competencies that include risk taking and brave, knowledge, values and self-confidence are vital for successful entrepreneurs. In addition, a review on the influence of other complementary infrastructures that include university's support to academic entrepreneurs in realizing technology entrepreneurship programme is also performed in this study. Indeed, we observed that the right entrepreneurial environment and enterprise infrastructure are important contributors in empowering academic researchers to produce innovations that are both technologically feasible and commercially viable.

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1. Introduction

Universities commonly known as the source of technological innovation play an important role in transferring university-invented technology and expertise to the market (Guerrero & Urbano, 2012). The commercialization of intellectual property or technology transfer has been viewed as engines of economic growth (Golob, 2006) and is also deemed important in creating a sustainable entrepreneurial environment (Guerrero & Urbano, 2012). In addition to their prevalent role in lecturing and performing research for publication, academics may also be perceived as key contributors in innovating towards commercialization (Fogelberg & Lundqvist, 2013). Academics who participate actively in creation and commercialization of university-invented technologies can also be termed as academic entrepreneurs (Libaers & Wang, 2012). For any method of technology transfer adopted by university, either licensing or start-up creation (Pe´rez & Sa´nchez, 2003), the likelihood of its success is largely influenced by academic researchers in playing their role as academic entrepreneurs (Wright, Birley & Mosey, 2004).

The aim of this study is to gain insights into the role of academic entrepreneur in the development of a university-based start-up that contribute to the successful commercialization of emerging technology. Specifically, the paper intends to explore the following research questions:

- What are the contributions of academic entrepreneurs in bringing out their scientific knowledge and university-invented technology from lab to market?
- What are the attributes of academic entrepreneurs and how such characteristics facilitate them in commercializing emerging technology?

To understand the extent to which academic researchers are the right translators of novel science-based technology in bringing innovations from lab to market, an analysis was performed based on case studies and publications pertaining to learning experiences of successful technology start-ups in developed countries. This paper is structured in the following way; firstly, it provides an overview of existing literature on nanotechnology and definition of academic entrepreneurs, highlighting their relation to technology transfer. This is followed by a discussion of selected case study on Richard E. Smalley, an academic entrepreneur who had successfully founded a start-up company to commercialize nanomaterial. The discussion relates the role of academic entrepreneur at various commercialization stages with entrepreneurial characters and other attributes that bring positive influence to the success of new venture creation. Finally, this paper concludes the review.

2. Academic entrepreneurship

Emerging technology has raised interest from many including researchers, economists, industrialists, policymakers and leaders from both developed and developing countries (Pandza, Wilkins & Alfoldi, 2011; Thukral, 2008). Many seek to embrace emerging technology due to its potential to create radically new products, (Allarakhia & Walsh, 2011) as well as to solve world problems (Tierney, Hermina & Walsh, 2013). Nanotechnology, an example of emerging technology (Groen & Walsh, 2013), is a convergence of nanoscience that offers promising applications capable of solving many global issues (Tierney, Hermina & Walsh, 2013). The increasing number of scientific publication in nanotechnology as depicted in Fig. 1 implies that academic researchers are actively exploring this emerging field.

However, the degree to which research outcomes are actually translated into commercial product and how this translation is influenced by the role of academic entrepreneur, have not been widely discussed in the social science literature on nanotechnology (Shapira, Youtie, Porter, 2010). Indeed, the tendency of physical scientists to publish more than their social scientist counterparts as illustrated in Fig. 2, is common amongst other emerging technology including micro-electro-mechanical systems (MEMS). Likewise, the literature on nanotechnology has been focusing largely on science and technology whereas the interaction between actors in technology diffusion has not been widely discussed (Nikulainen, & Palmberg 2010). This suggest further study is needed to develop understanding on role of academic entrepreneur in commercializing emerging technology to the development and growth of social science research in nanotechnology.

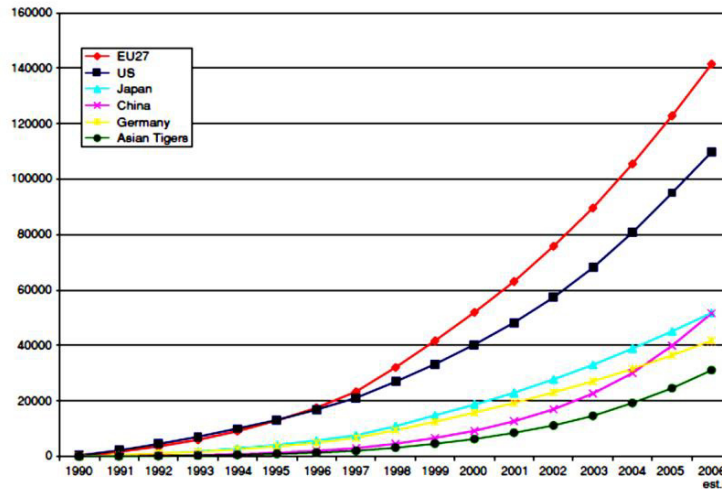


Fig. 1. The increasing number of scientific publication in nanotechnology according to countries¹ (Youtie, Shapira & Porter, 2008)

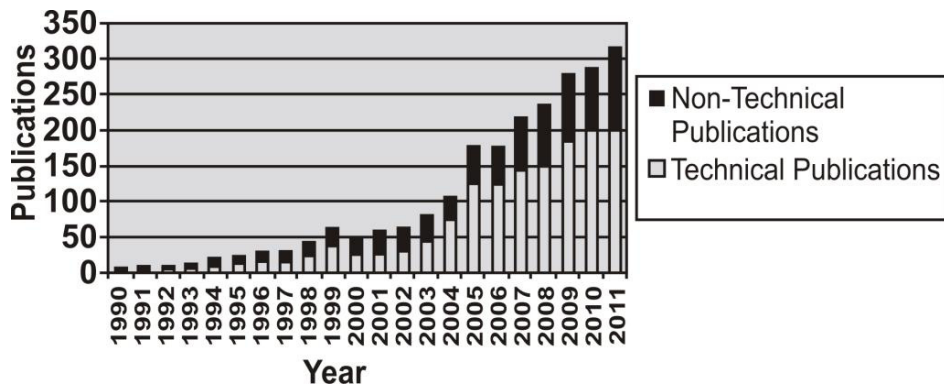


Fig. 2. The tendency of physical scientists to publish more than their social scientist counterparts as indicated by the number of technical papers and non-technical papers in MEMS field. Source: Scopus, September 2012 (Groen & Walsh, 2013)

Academic entrepreneur is defined as “an academic whose primary occupation, prior to playing a role in a venture start-up, and possibly concurrent with that process, was that of a lecturer or researcher affiliated with Higher Education Institute” (Samsom & Gurdon, 1993). The designation of academic entrepreneur is also used to describe involvement of academic researchers in the process of identifying commercialization opportunity and technology transfer of research outcomes (Lockett, Siegel, Wright, Ensley, 2005). Being the technology originator, academic researcher who also assume the role of entrepreneur (Franklin, Wright & Lockett, 2001) is perceived as the key actor (Jain, George & Maltarich, 2009) in exploiting university invented technology and bringing it out for commercial use.

¹ Cumulative annual counts from Web of Science, Science Citation Index (SCI), 1990–2006 (estimated). (EU27 = European Union 27 member countries as of 2007 and Asian Tigers = South Korea, Singapore, and Taiwan) Source: Analysis by the Program in Research and Innovation Systems Analysis, Center for Nanotechnology and Society (CNS-ASU) at the Georgia Tech Technology Policy and Assessment Center (Youtie, Shapira & Porter, 2008)

A stream of research has followed to understand factors that drive academic researchers to move from their traditional role as producer of research to an active contributor in technology commercialization. For example, the tendency of academic researchers to involve in entrepreneurial activity can be influenced by their prior experiences as well as their education background (Shane, 2000). Prior experiences, including working experience in private firms or collaboration with industry (Fritsch & Krabel, 2012) expose academic researchers to real industrial problem and market needs. Such exposure enable academic entrepreneurs to recognize and develop potential technological solution with commercial values. Apart from internal factors, the right entrepreneurial environment is an important external factor that indirectly pull academic researchers towards commercialization-focused activity. For instance, peer influence and university's culture that emphasize both productivity in research and commercialization will encourage more academic's participation in entrepreneurship (Stuart & Ding, 2006).

Despite the fact that academics possess a strong technical ability to be the technology inventor, many argue that academic researchers are unfit for entrepreneurial activity. Although academic researchers are capable to invent and develop a good innovation, they may not have the necessary business skills and social capital which are essential in realizing technology transfer (Venkataraman, MacMillan & McGrath, 1990). Due to the lack of business knowledge, they are claimed to have tendency in focusing more on technical aspects than business aspects of their innovation (Franklin, Wright, & Lockett, 2001). This often results in their business proposals to be more technology-push oriented than in capturing market opportunity (Wright, Hmieleski, Siegel & Ensley, 2007). On top of that, the conflicting role identity (Jain, George & Maltarich, 2009) between entrepreneurs and researchers may affect their focus and performance on either activity. In this comparison, the former is usually driven by publications and peer recognition whereas the latter is driven by products and profits. It will put more work demands on academic entrepreneur to integrate both roles which may affect their ability and subsequently impede commercialization process.

Regardless of negative claims above, the role of academic entrepreneur is deemed imperative in commercialization of emerging technology. Commercialization of nanotechnology for example, is a scientist-driven process due to its technology nature which is still at early development phase (Nikulainen, & Palmberg, 2010) and many innovations actually originate from university. The evolution of nanotechnology is largely depends on degree of translation of research outcomes to commercial application, in which academic entrepreneur is the key actor in the transfer process. Indeed, most of the nanotechnology start-ups began as spin-offs from universities and research laboratories (Brad Spurgeon, 2001) where academic entrepreneurs are the main contributors in early development and commercialization. In the United States, seven (7) entrepreneurs from renowned universities had been interviewed to share their success stories in technology commercialization (Petkewich, 2009). The interview as reported in *Chemical & Engineering News*, highlighted that these entrepreneurs are chemistry professors with entrepreneurial spirit who have founded at least one start-up company to commercialize their research outputs. For example, George M. Whitesides, a chemistry professor from Harvard University had founded a nanotechnology start-up company, Nano-Terra in 2005 to commercialize soft lithography techniques developed in his lab. The academic entrepreneur, Professor Whitesides had also co-founded another start-up company, Semprius in 2004 to commercialize stamping and printing technology for silicon nanoribbons onto glass and plastics. In terms of technical experiences, Professor Whitesides has been developing his scientific expertise in chemistry since 1960s (Kevin Bullis, 2007) and has been regarded as amongst the world's most highly cited scientist in material research (Whitesides, 2002). It is believed that for successful new technology venture creation, entrepreneurs should possess a combination of different skill sets to face challenges in various stages of commercialization process. With sufficient and supportive infrastructure for technology transfer in place, academic entrepreneurs may form start-up companies and make profits based on intellectual property generated from these innovations. Subsequent section will provide a discussion on relation of the role of academic entrepreneur with entrepreneurial characters and other attributes that bring positive influence to the success of new venture creation.

3. Commercialization of research output

3.1. The role of academic entrepreneurs and their associated attributes

a. Discovery and identification of technological opportunity

Academic researchers are commonly associated as individuals who hold technical qualifications at highest academic level. Highest academic qualification, combined with vast research experience, imply that academics have been developing scientific expertise and technical skills sufficiently for them to be regarded as experts in a particular technology field. High technical skills and scientific research excellence are believed to build the capacity of researchers to continuously invent, innovate and contribute to the development of technologically advanced products (D'Este, Mahdi, Neely, & Rentocchini, 2012). Such abilities are essential and serve as starting point in commercialization of emerging technology. Indeed, many empirical research in the past have shown how academic researchers' engagement in commercialization activities is greatly influenced by their superior academic performance (Louis, 1989, Deeds, 1997, Powers & McDougall, 2005, Meyer, 2006, Landry, 2007).

Richard E. Smalley (1943-2005), a chemistry professor from Rice University, is a prominent model of academic entrepreneur in nanotechnology. Throughout his career life, Smalley had successfully leverage over his high scientific expertise to invent and innovate towards the development of profitable technological products. Smalley's research excellence has been highlighted with the discovery of nanomaterial, fullerene molecule (Nobelprize.org, 1996) which led to the award of Nobel Prize in Chemistry in 1996. Apart from high scientific expertise, it is believed that Smalley's inventive attribute helped him to develop necessary mindset and skills that brought him to such remarkable discovery (Shane, 2000, Shane & Venkataraman, 2000). The discovery and identification of technology opportunity indeed highlight the first stage of commercialization process led by an academic entrepreneur.

b. Exploitation of commercial opportunity

Past study on the relation of academic entrepreneurs' attributes to commercialization outcomes highlighted that, motivation and inclination to engage in applied research are entrepreneurial characteristics that will increase the probability of success in technology commercialization (Marion, Dunlap, Friar, 2012). Smalley's entrepreneurial motivation after the discovery of *fullerene*, is portrayed by his research focus that turned to carbon nanotubes (CNT) and the application of their extraordinary properties in energy sector (Smalley Institute, 2008). It is believed that his strong confidence in the commercial potential of CNT's unique properties[‡] had influenced his decision to steer into new research focus. A strong entrepreneurial motivation and high confidence as exemplified by Smalley are important attributes of academic entrepreneurs in their role to exploit commercial opportunity of their research outcomes. Indeed, a strong self-belief (Renault, 2006, Marion, Dunlap & Friar, 2012) and courageous action to change research orientation towards meeting the business needs (Thursby & Thursby, 2002) have placed Smalley in the right direction in becoming a successful academic entrepreneur.

Industrial working experience or research collaboration with industry will positively influence the ability of researchers to exploit commercial opportunity of their research outcomes (D'Este, Mahdi & Neely, 2010). Engagement with real life applications enable researchers to accumulate tacit knowledge (Arrow, 1962) and develop a unique skill sets (Marion, Dunlap & Friar, 2012) that benefit their role as academic entrepreneur to face new challenges in bringing research outcomes from lab to the market. Smalley's research passion which had changed to application of CNT in energy sector, is also believed to be influenced by his prior engagement with the industry. A written source from Rice University (Adams & Baughman, 2005) reported that Smalley once stated: '*These (referring to his industrial experiences) were fascinating days, involving huge volumes of material, serious real-world problems, with large financial consequences*'. His industry experience as quality control chemist at Shell Chemical Company (Nobelprize.org, 1996) had provided him with an exposure on industrial-scale processes which benefit him when he initiated efforts to commercialize CNT (Adams & Baughman, 2005).

c. Development of technological product beyond lab's expectation

[‡]Nowadays, commercial application of CNT include the incorporation of its powder form in rechargeable batteries, automotive parts, sporting goods, boat hulls and water filters. CNT sheets are also used for supercapacitors, actuators and lightweight electromagnetic shield. (De Volder, Tawfick, Baughman & Hart, 2013)

Commercialization of emerging technology is a challenging and lengthy process that demands roles of academic entrepreneur to be more than discovery of technological opportunity and exploitation of commercial opportunity (D'Este, Mahdi, Neely & Rentocchini, 2012). In bringing research outputs closer to the market, the next stage is the development of technological product beyond lab's environment that meets customer expectations. As for Smalley's case, the identification of remarkable property of CNT was merely a starting point, but his effort in scaling up the production of CNT opened the lab's door and brought the nanomaterial closer to users. At this stage, scientific expertise and technical skills were again crucial as Smalley moved beyond lab's expectation and developed technological process (Cyrus, 2010) to produce CNT at both high yield and good quality. Although this paper focuses more on roles of academic entrepreneurs in creating successful start-up than in sustaining one, it is worth to highlight that their roles during early days indeed have influences on the sustainability of the start-up. The ability of academic entrepreneurs to leverage their technical skills in scaling up production process with economies of scale and good quality control during early days are essential for growth and sustainability of new venture.

Strategic thinking is another imperative attribute as it may facilitate academic entrepreneur to devise a creative pre-commercialization approach. Smalley's approach ahead of start-ups creation was by first providing other researchers access to high quality CNT that his team produced in Rice University. A service center, *Tubes@Rice* was formed in 1998 to increase the number of researchers in nanotube application (Cyrus, 2010). Although it was a non-profit effort, this strategic approach allowed Smalley's team to explore the market and gather useful commercial information about CNT's application as buyers had to indicate the purpose of their purchase. Smalley's risk-taking move during this stage proven successful to create early customer demands that eventually led him to founding a start-up company, Carbon Nanotechnologies Inc. a year later.

Richard Smalley's journey in commercializing emerging technology discussed until this point can now be categorized into three (3) main roles of an academic entrepreneur. For each role, significant attributes and their associated drivers are summarized in Table.1.

Table 1. Roles of academic entrepreneur in commercializing emerging technology

Role of academic entrepreneur	Discovery & Identification Of Technological Opportunity	Exploitation of Commercial Opportunity	Development of Technological Advanced Product
Specific Attributes	High technical skills High scientific research excellence	Entrepreneurial motivation Strong inclination towards commercialization	High technical skills Commercialization planning
General attributes	Creative, Innovative, Risk-taking, Determination, Confidence		

3.2. The role of university in providing entrepreneurial infrastructure that supports technology transfer

Success of technology commercialization is not solely dependent on academic entrepreneur but also contributed by university's support in providing entrepreneurial infrastructure that include good intellectual property management system (Thursby & Thursby, 2002; Shane & DiGregorio, 2003) and efficient technology transfer office (TTO) (Debackre & Veugelers, 2005). Specifically for an environment with weak entrepreneurial cultures and infrastructures, university play an important role in creating spin off policies with high selectivity and high support to promote venture creation amongst academic entrepreneurs (Degroof & Roberts, 2004). As for Smalley's case, Rice University established a service centre named *Tubes@Rice* in 1998 whereby at that particular of time, the university had no technology transfer office and its patenting activity was very low. Despite being new to intellectual property (IP) management and technology transfer, Rice University had been very supportive to Smalley's team in realizing their vision on technology entrepreneurship. Thus, Rice University initiated effort to seek for external consultancy in setting up technology transfer office, following which patents committee was also formed (Edward & Frank, 1998) to support Smalley's work to cofound a start-up. It is worth to highlight that university's role in realizing technology entrepreneurship is not just by establishing TTO and IP management, but university needs to ensure TTO's capacity and staff's competency to deliver smooth and reasonably quick support to

academic entrepreneurs. This is essential to attract active involvement of academic researcher in commercialization activity (Owen & Powell, 2001).

4. Conclusion

The successful CNT commercialization through the formation of Carbon Nanotechnology Inc. founded by Richard Smalley indeed highlight that academic entrepreneurs play an important role in the commercialization of emerging technology (Fogelberg & Lundqvist, 2013). The intelligence, skills and ability of an academic entrepreneurs to recognize technological opportunity, to exploit commercial opportunity and to develop technological advanced product are primary characteristics that outline their role in technology entrepreneurship. Being equipped with such roles, academic entrepreneurs are apparently the key actor who responsible for commencing the commercialization process in university. In facing various challenges to bring out technological product from lab to market, it is also essential for academic entrepreneur to have the right entrepreneurial attitude such as creative, innovative, risk-taking, high determination and self-confidence. In addition, university needs to complement this effort by providing the right entrepreneurial environment and enterprise infrastructure. A supportive policy, a good IP management system and an efficient technology transfer office are crucial in empowering academic entrepreneurs to produce innovations that are both technologically feasible and commercially viable. In general, academic entrepreneurs who possess entrepreneurial competencies and capable of exploiting commercial-based research will undoubtedly contribute to the acceleration of techno creative-innovation towards sustainable entrepreneurial environment. So far this paper only discussed the role of academic entrepreneur in commercializing carbon nanotube in developed country. There are more areas that can be reviewed and investigated including commercialization of other nanotechnology products and comparison of academic entrepreneur's role between developed and developing countries.

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