Technology Based Academic Entrepreneurship: How Little We Know

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Developing new innovations is at the core of what research universities do. While it is common knowledge that universities are an integral part of creating new innovations, what is not so well known is how these innovations make their way to commercialization. There are very few studies that provide understanding into the role and impact of technology based academic entrepreneurship. This paper systematically goes through the major areas of the literature and identifies the important knowledge gaps. It parcels the literature into four main areas: (1) university technology transfer, (2) business-science faculty interface, (3) venture capital, and (4) complementary assets. At the end of the paper a new model of technology based entrepreneurship is offered. The end result of this paper is a significant contribution to the understanding of where the knowledge gaps in technology based academic entrepreneurship exist and what areas need particular scholarly attention.

INTRODUCTION

Developing new innovations is at the core of what research universities do. In 2011 six percent of U.S. patents were filed by U.S. universities (Schuetze, 2011). Many of the patents are commercialized through university spin-offs (USOs) or licensed out. However, little is known on how university research is transferred to the market and how universities and faculty members engage in technology based entrepreneurship.

While it is common knowledge that universities are an integral part of creating new innovations, what is not so well known is how these innovations make their way to commercialization. For over fifty years, researchers have been looking at this topic, but a universal understanding has yet to emerge. One area of this that has been well researched is the university setting itself (Grimaldi and Scarabotti 2013). Locket and Wright (2005) suggest that a universities stock of resources and capabilities is the driving factors that determine spin-off propensity from universities; i.e., well-funded universities with better capabilities produce more USOs. Di Gregorio and Shane (2003) show three things are associated with new business formations: The first is the intellectual eminence of the university. The second is that equity investments in the technology licensing offices, and the third, and surprising finding, is that a lower royalty for the inventor was associated with an increase in new firm formation – which is contrary to what conventional wisdom would indicate. O'Shea et al. (2005) found that successful technology transfer was related to faculty quality, funding, and the scientific orientation of the university.

Another group of researchers have examined the individual characteristics of academics on entrepreneurship. Owen and Powell (1998) found that scientists from different areas have different orientations towards entrepreneurship; e.g., computer scientists have a more entrepreneurial nature than biologists do. Laukkanen (2003) suggests that the culture of a university has a big impact on the

entrepreneurial activity of faculty members. Some universities encourage faculty members to get involved in new ventures, while in others it is often looked down upon. In a similar vein, Bains (2005) looked at the top scientific academics in the UK and found that most of them are interested in generating income outside of the university, but for most academics this comes from consulting jobs.

While the overview above provides a good understanding of the basic overarching dynamics of technology based academic entrepreneurship, little is known beyond the surface level on the topic. There are very few studies that provide understanding into the role and impact of technology based academic entrepreneurship. The sparse literature has left many unanswered questions relating to the topic. This paper systematically goes through the major areas of the literature and identifies the important knowledge gaps. It parcels the literature into four main areas: (1) university technology transfer, (2) business-science faculty interface, (3) venture capital, and (4) complementary assets. At the end of the paper a new model of technology based entrepreneurship is offered. The end result of this paper is a significant contribution to the understanding of where the knowledge gaps in technology based academic entrepreneurship exist and what areas need particular scholarly attention. Furthermore, the model offered in this paper is a potential framework for studying technology based academic entrepreneurship.

UNIVERSITY TECHNOLOGY TRANSFER

One of the main ways that academic entrepreneurs enter into the market place is through USOs; i.e., companies that are developed around university innovation. These companies have received a lot of attention in the press over recent years. However, the scholarly literature has not properly examined this topic.. The small number of studies on USOs suggests that they perform better than non-spin-offs. Shane (2004) shows that academic spin-offs are 108 times more apt to going public than non-USOs. In a similar vein, Rothaermel and Thursby (2005) looked at 79 university incubator firms and found that they have a much higher survival and IPO rate than non-university affiliated firms. Studies on Australian (Zhao 2004), French (Mustar 1997), Irish (Klofsten and Jones-Evans 2000) and Swedish (Dahlstrand 1997) firms have shown remarkably low failure rates. Furthermore the AUTM (2001) survey showed that over 2,200 of the 3,376 spin-offs founded from 1980 and 2000 have survived. However, not all of the studies have found that USOs have superior performance compared to non USOs. Ensley and HMieleski (2005) looked at a match sample between 102 high tech USO and 154 high tech non-USO startups and found that the USOs had lower revenue growth and poorer cash flow. They attributed this to the less developed and dynamic top management teams. In a similar vein, Rammussen and Mossey (2011) show that USOs demonstrate mixed performance results as compared to non-USOs. They contend that there a myriad of factors that make it difficult to truly gauge USOs, but as a whole, USOs do perform better.

There is a glaring shortage of studies that properly examine the performance of USOs. Until more work is completed, the overall performance of these firms will stay a mystery. Specific work is needed on long-term performance, speed of commercialization, and impact that USOs have. Although ceteris paribus comparisons will be difficult because of private and often secretive nature of startup firms, there are ways to compare spin-off to non-spin-offs. For example, Wennber, Wilklund, and Wright (2011) isolated the knowledge intensive university and corporate spin-offs from over a ten year period in Sweden. They then compared the major performance indicators of the two groups of firms. As this paper shows, there are methods and ways of extracting comparable data.

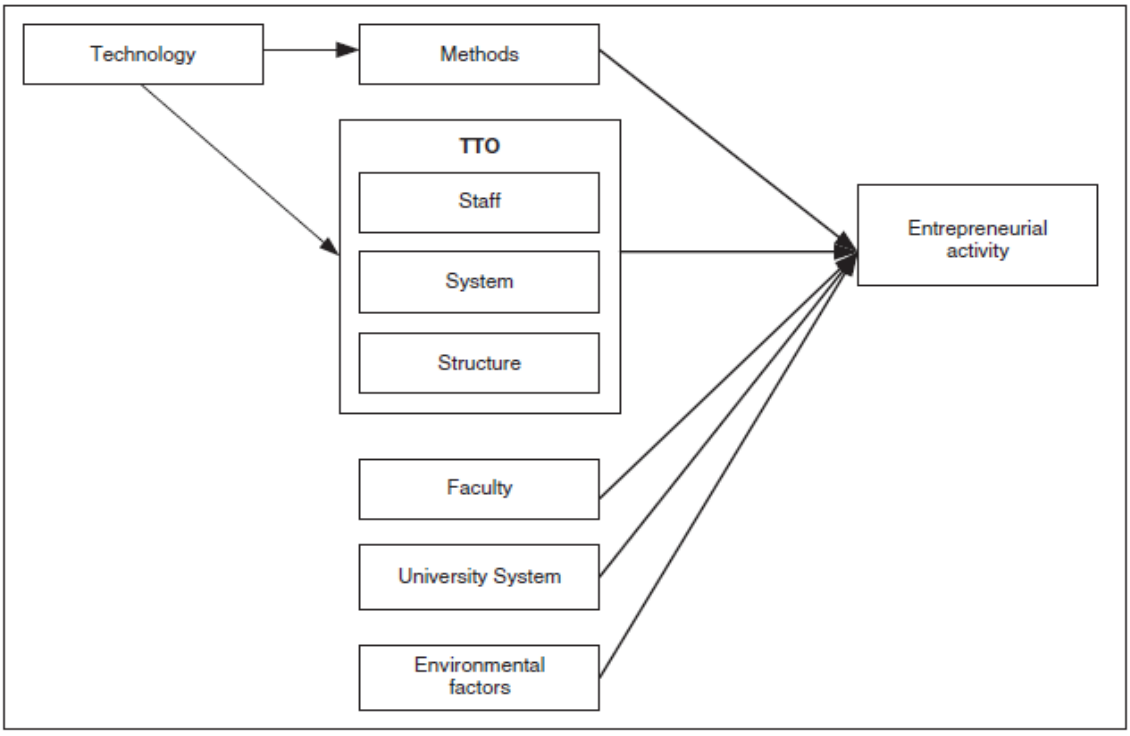
Most innovations that are commercialized are not done so through spin-offs. Instead, the innovations are most often licensed or sold through a technology transfer office (Rasmussen et al. 2011). Many top research universities have established a technology transfer offices, and others outsource this function. These offices are intended to serve as the liason between university born technologies and industry. Their main function is to setup agreements for the use of these technologies, so that the university and the founding professor(s) can share in the revenue that the innovations generate. These agreements usually come in three forms: equity, joint venture, or licensing. Based on four in depth case studies Wright et al. (2004) suggest that joint venture spin-offs are better than venture capital (VC) backed spin-offs. This is because VC backed USOs face four challenges that joint venture spin-offs do not: (1) problems with

opportunity recognition, (2) troubles attaining a venture champion, (3) problems garnering credibility, and (4) challenges sustaining in the market. On the other hand, their findings also suggested that there may be control problems. This idea is supported in the joint venture literature, which has shown that small firms are often in a merciful position when partnering with larger firms (Coviello and Munro 1995; Hladik 2002). Moreover, in many cases innovators get VC investment before they look for joint venture partners because their innovation is not at a stage where larger firms would be interested in it; therefore a joint venture may not be an option for the innovators. The third way that technology transfer offices disseminate innovations is through licensing; they sell the rights to an organization outside the university.

There has mixed results on which of the three ways of commercializing university innovations is the most optimal. The answer seems to be that "it depends". That is, it depends on the nature of the innovation and the institutions involved. Put differently, any of the three ways could be superior given the right circumstances. What has not been established is the effectiveness of university TTOs. Several studies have looked at what makes some offices more successful than others. Siegel et al.'s (2003) empirically robust study based on 55 interviews with different stakeholders of USOs indicated that the TTO model has some inherent flaws. Most notably, was the 70% of the faculty members who indicated that the reward system for faculty involvement was insufficient. Faculty members felt that the university was taking too much of the split to make working with TTOs worthwhile for the faculty members. This study also found that there was widespread dissatisfaction with marketing and negotiation skills of the personnel in the TTOs. Furthermore, the interviewees from the study almost unanimously supported developing a holistic approach to developing a mutual understanding of all of the stakeholders. This study was followed up by Siegel et al. (2004), which suggests that four factors directly related to TTOs that help foster the success of TTOs: (1) proper reward systems for the TTO employees, (2) the incorporation of a flexible university policies which incorporate the TTO in the overall organization, (3) eliminating cultural and informational barriers that disrupt the TTOs activities and (4) providing enough resources to the TTOs. The fourth factor is supported by Lockett and Wright (2005), which found that resources are critical to the success of technology offices. This study further indicates that capabilities are just as critical as resources; i.e., TTOs need highly trained staff capable of handling complex transactions, and facilitating the creation of spin-offs. These findings are further supported by Debackere and Veugelers (2005) who propose that universities should offer proper incentives to reward academic entrepreneurship, TTOs should have decentralized operating structures to provide greater flexibility, and TTOs should also have a experiences and skilled staff in a centralized TTO.

In Figure 1 below Rothaermel (2007) offers a model of what a TTO should encompass. This is the best model on the topic offered to date. It does an excellent job of encompassing the many factors that go into TTO productivity. However, it simplistic, and does not fully conceptualize how all of the variables interact. Furthermore, it fails to fully capture the element of time. USOs develop over time, and it is critical for TTO models to encompass time (Cardozo, Ardichvili, and Strauss 2011).

FIGURE 1
PRODUCTIVITY OF TECHNOLOGY TRANSFER OFFICES



Technology

- Stage

(e.g., Thursby and Thursby, 2001)

Methods

- Financial returns of licensing vs. equity
- Licensing strategy
- Effectiveness of patent
- Project selection and evaluation

(e.g., Bray and Lee, 2000)

System

- Incentives for TTO staff
- Resources
- Degree of self-sufficiency
- Balancing university and faculty objectives

(e.g., Jensen et al., 2003)

Structure

- Reporting relationship
- Autonomy
- Age

(e.g., Bercovitz et al., 2001)

Faculty

- Propensity to disclose
- Shift of research focus
- Disclosures

(e.g., Thursby and Thursby, 2002)

Staff

- Admin propensity to license
- Admin ability and activity to market

(e.g., Markman et al., 2005a)

University system

- Intellectual property protection
- Culture
- Public/private
- Incentive system for faculty
- R&D intensity
- Departments (e.g. medical school)

(e.g., Siegel et al., 2003b)

Environmental factors

- Industrial research support
- State-level economic growth
- R&D activity of local firms

(e.g., Feldman et al., 2002)

Source: Rothaermel et al. (2007, p. 747)

Discussed above were university related factors related to the transfer of technology. Most of these studies isolate the motivation for academic entrepreneurship. More work is needed to hold factors constant to see what the best practices are for TTOs. There are many TTOs performing much better than others. It is not a fair to look at the very top universities and say their TTO office is performing the best when they have one of the highest rated science faculties and one of the largest funding endowments – naturally they should have the most productive TTO. On the other hand, The University of Utah and The University of Georgia were both in the top ten in terms of productive TTOs in the United States from 1980-2001 (O'Shea, Allen et al. 2005), yet neither are in the top 100 in terms of scientific faculty ranking or funding. This indicates that they may have highly effective TTOs. However, this needs to be properly examined. Quality research on this topic might lead towards a more effective TTO model. More studies need to follow Lockett and Wright (2005) in performing in examining the best TTOs through in depth qualitative work.

BUSINESS-SCIENCE FACULTY INTERFACE

One area that has been left largely untouched is the business-science faculty interface in technology based academic entrepreneurship. The vast majority of studies look at the activities of science faculty members in commercializing their innovations, but there is no study of note on the role that business schools play in facilitating the commercialization of innovations. Theoretically business schools have a wealth of knowledge on planning, networking, negotiating and financing new business ventures. Furthermore, opportunity recognition is an important aspect of entrepreneurship (Gaglio and Katz 2001; Ardichvili, Cardozo et al. 2003). Science faculty members are highly trained in their fields, but most lack expertise, training, and experience in entrepreneurship (Nicolaou and Birley 2003). Business faculty are trained and experienced in this area and could be a great asset in the identification of opportunities.

There is evidence through business school curriculums that the business faculty is interacting with the science departments. This is most evident through the courses being offered to scientists on starting a tech business. It is also evident through the outreach programs at universities. For example, the University of Glasgow Department of Management hosted a Life Sciences Ventures seminar for industry practitioners and science and business academics. Similarly, the Sloane Business School at MIT offers several seminars a year for scientists on technology based entrepreneurship. While it is clear from the anecdotal evidence that there is a connection between business and science faculties, there is real need for empirical research to establish the nature of this relationship. This research needs to establish what types of interactions these two faculty members have: Is there a close relationship? Are the business faculty members consulting with the science faculty members on the commercial potential of the science innovations? These are just two of many areas that need addressed on this topic. There are so many unexplored areas on this topic that it could eventually become a unique stream of literature.

VENTURE CAPITAL

The relationship between venture capital (VC) and university technology offices is another underserved area in the literature. Wright et al. (2006) suggest that there is an imbalance between the supply and demand of VC for USOs. More specifically, they contend that VCs prefer post seed stage investment, whereas the spin off firms prefer a seed stage investment. This article also underscores the shortage of quality research on VC and academic entrepreneurship and calls for future studies to explore the relationship between spin offs and external financing. Similarly, McAdam et. al (2012) suggest that the lack of funding for spin-offs is one of the primary reasons as to why USOs are not more prolific.

It is surprising that there is such little research that has explored this topic, even though there has been a clear connection in clusters between universities, industry, and VC (Florida and Kenney 1988; Powell, Koput et al. 2002). Mason and Harrison (2004) study suggests that one of the biggest challenges in establishing a cluster near a university is attracting VCs to the area. DiGregorio and Shane (2003) found that there is no evidence that the presence of VC are related to spin-off activity. However, this study only

looked to see if the location of VC mattered, so the study looked at to see if the VC within a sixty mile radius had an effect. While an interesting study, its methods are questionable and it ignores that VC has become more flexible in investing in areas outside of their location, so it follows that location is not as important anymore. Moreover, section 2 in this paper established that VCs provide more than just finance, and that their value added activities are especially beneficial to entrepreneurs that lack business experience (Hellmann and Puri 2002). Conventional wisdom would indicate that most university science professors would not have significant business experience. Thus it follows that VCs would be especially beneficial to USOs. However, research is needed to substantiate this.

Lerner (2005) highlights the failed attempts of universities to start their own internal VC. Several of the top research institutions with large endowments (e.g., Boston University, University of Chicago, and University of Illinois) attempted to finance their own spin-off firms. The outcomes were all less than desirable, and the schools lost considerable sums of money. He attributes the lack of success to the programs failure to recruit and attain the best talent, regulations restricting researchers' involvement, and political interference. Lerner also points out institutions that have had considerable success in working with outside VC to spin-off companies—namely Stanford and MIT. These institutions have a following of VCs that invest in their spin-offs. This fact and the fact that these schools have had such strong spin-off performance also underscore the need to further examine the influence of VC on technology based academic entrepreneurship.

There are several areas that need to be probed in the VC university technology transfer relationship. The first of these is how important is it for a university to have an extensive presence of VCs. In the discussion above the evidence is contradicting; with some studies emphasizing the importance of VC in an area (Florida and Kenney 1988; Powell, Koput et al. 2002), while others indicating it is not important (DiGregorio and Shane 2003). Another area that needs to be explored is what role the VCs take in the spin-offs that they invest in. VCs take on different roles depending on the type of investment and the stage that they invested in. On some occasions, especially when the VCs invest in early stage companies, they will have a lot of input in the firms operations; whereas in other cases the VCs will invest money and will act very similarly to a bank—not having much input in the firm's operations. A third area that needs to be addressed is how active the VCs are in networking in the spin off firms that they invest in—it would be especially interesting and relevant to see how vital their network ties are to establishing complementary assets (CAs).

COMPLEMENTARY ASSETS

CAs are the auxiliary assets needed to commercialize an innovation (Teece, 1986). For example, a drug might need a specialized testing done in order for it to make it to market. In this case the testing would be a complementary asset. CAs has been all but completely ignored in the academic entrepreneurship literature. This is surprising considering how import CAs are—especially SCAs—to the commercialization of innovations. Lockett et al. (2005) is one of the few papers that recognizes this importance. They identify three key complementary assets: (1) technology, (2) human capital and (3) finance. Figure 2 is the matrix they develop to explore the inputs and stages that go into developing a USO.

FIGURE 2
THE KNOWLEDGE MATRIX GAP

	Research	*Opportunity*	*Pre-organization*	*Re-orientation*	*Sustainable*
PRI					
TTO					
Incubator					
Venture					
Team					
Individual					

Source: Lockett et al. (2005)

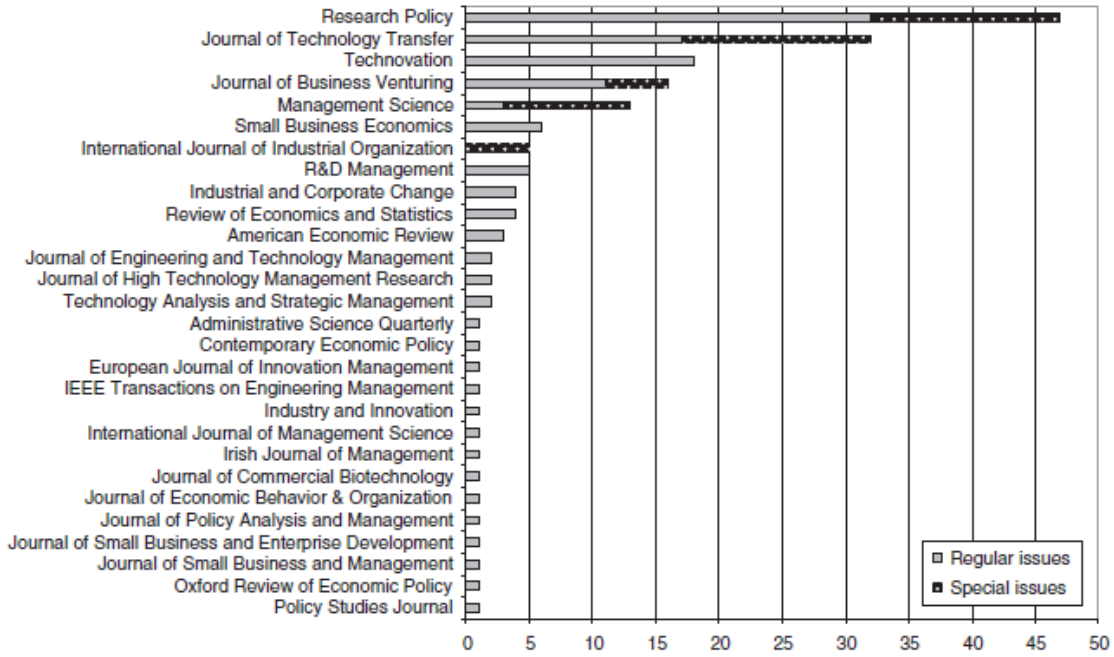
In this matrix they identify the important sources of inputs and the important stages in a USO's development. From this they identify a number of knowledge gaps that the literature needs to looks at. For example (p. 985): How the knowledge in the management team develops? How knowledge is acquired from different parties and to what extent and when should the university have a role in the development of the spin-off? While all of these are good questions and would make for good studies—a more interesting question is how each of the input sources contribute to development of complementary assets that are needed in commercialization? One particular CA that universities contribute to is complementary technologies. Universities are a rich source of R&D and technologies that industry is heavily reliant on; yet little research has examined the university as a source of R&D CAs.

Perhaps the reason so little work in academic entrepreneurship has looked at CAs is that most studies on academic entrepreneurship have looked at the topic from the viewpoint of the university or academic faculty member's perspective; very few papers have looked at how the university provides services that could be viewed as CAs. There is a need for studies to isolate the services universities provide to new technology based firs (NTBFs), and to examine whether these services are CAs, and if so, how impactful these services are on NTBFs.

NEW MODEL

The discussion throughout the course of this paper has indicated that technology based academic entrepreneurship has been looked at more from the university and science perspective than from the perspective of NTBFs. This assertion is further back up by Figure 3, which presents the articles on academic entrepreneurship published from 1981-2005.What is significant about this chart is that the management journals have far fewer articles published in them than the policy and technology journals; thus showing that research has been far more concerned with the development of technology than the development of NTBFs.

FIGURE 3
ACADEMIC ENTREPRENEURSHIP ARTICLES



Source: Rothaermel (2007)

The literature has become focused on the university and science and has neglected analysis from the firm's perspective. There is little work that has provided a taxonomy of the firms involved with academic entrepreneurship. The annual AUTM survey of university technology transfer provides descriptive statistics of university technology transfer, but it does not provide any depth into the nature of the transfers; e.g. there is no way to decipher from this survey how many companies were formed from innovations versus how many companies came to the university to find technology to start or enhance a young venture. Furthermore, there is little data available on when a NTBF reaches out to universities to help the NTBF develop a needed technology; e.g., when a NTBF needs a CA such as testing capabilities and partners with a university for the universities technology capabilities. Grandi and Grimaldi (2005) looked at 40 Italian NTBFs and found that relationships with external organizations is key to the success of these firms. Similar findings were presented by Gubeli and Doloreux (2005) who suggest that relationships with outside organizations are critical to providing key complementarities. This study did not discuss the importance of CAs, but the findings suggest that the outside organizations, such as universities, were instrumental in providing CAs needed to commercialize the innovations of NTBFs. These studies provide some insight on the importance of the university in helping non-spin-off firms, but there is still much to be answered in regards to how these firms interact with universities.

Rahm (1994) study of over 1,000 academic researchers found that over 75% engage regularly in consulting, and over 80% have former students in industry that they are in regular contact with. Similarly, Ameida, Hohberger, and Parada (2011) show interorganizational collaborations between industry and scientific faculty is an important driver to new innovation. From studies like these, it is evident that in many cases firms come to the university in the search of assistance. What has not been deciphered is the number of new firms that are coming for assistance; this is a topic that needs exploration. Regardless of what type of firm the academic is consulting with, it is evident that academics are engaging in an entrepreneurial activity; i.e., they are engaging in a profit seeking endeavor for themselves. Perhaps they are more interested in the science behind the consulting job, but conventional wisdom would make it hard to imagine that most of them are not interested in the profit motive.

The discussion in this section has highlighted the process of academic entrepreneurship. Rothaermel's (2007) model underpins the process of academic entrepreneurship, but it fails to encompass both inward and outward entrepreneurship. To compensate for this Figure 4 and 4a below offer a simple inward and outward model of university entrepreneurship. In the outward model the innovation is begat at the university and then commercialized through the TTO. The TTO takes the innovation and has three options: (1) to work with the university scientists and VCs on forming a new company; (2) find established firms to partner with in an equity sharing agreement; and (3) license the rights to the technology to established firms. In the inward (Figure 4a) firms come to the university is search of assistance. For example, a firm may need specialized testing or a specialized compound to be developed to make their innovation commercially viable. In this instance the firm may come to the university in search of assistance. At this point the university may enter into a (1) a consulting agreement or (2) a joint venture of some nature.

FIGURE 4
OUTWARD MODEL

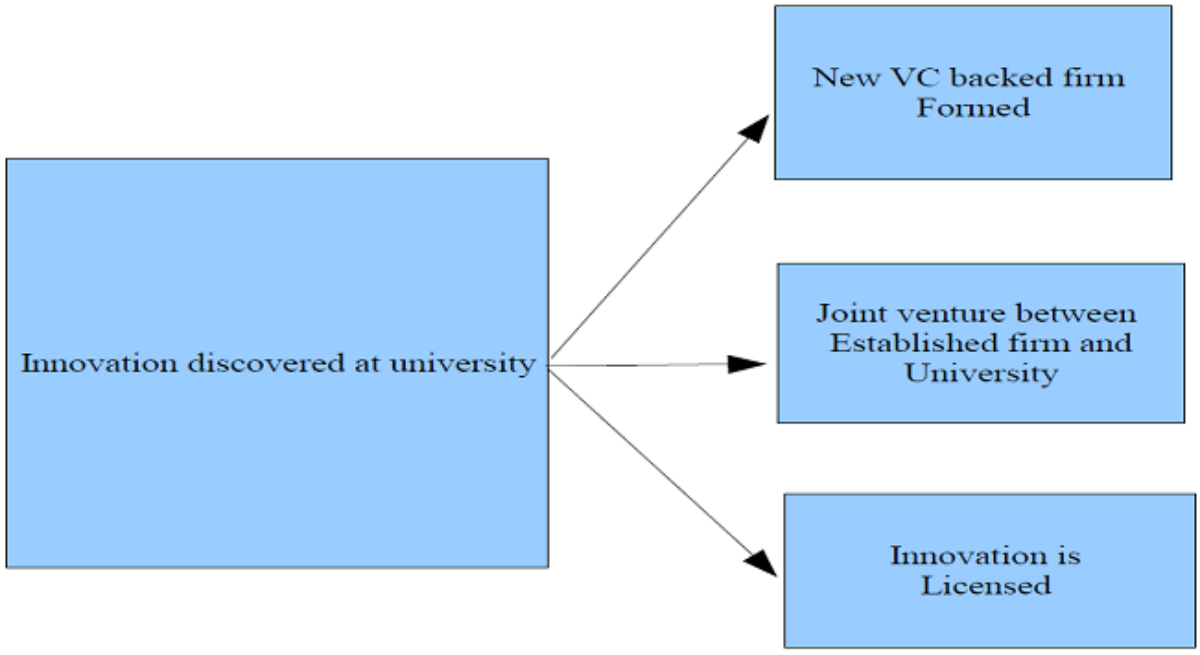
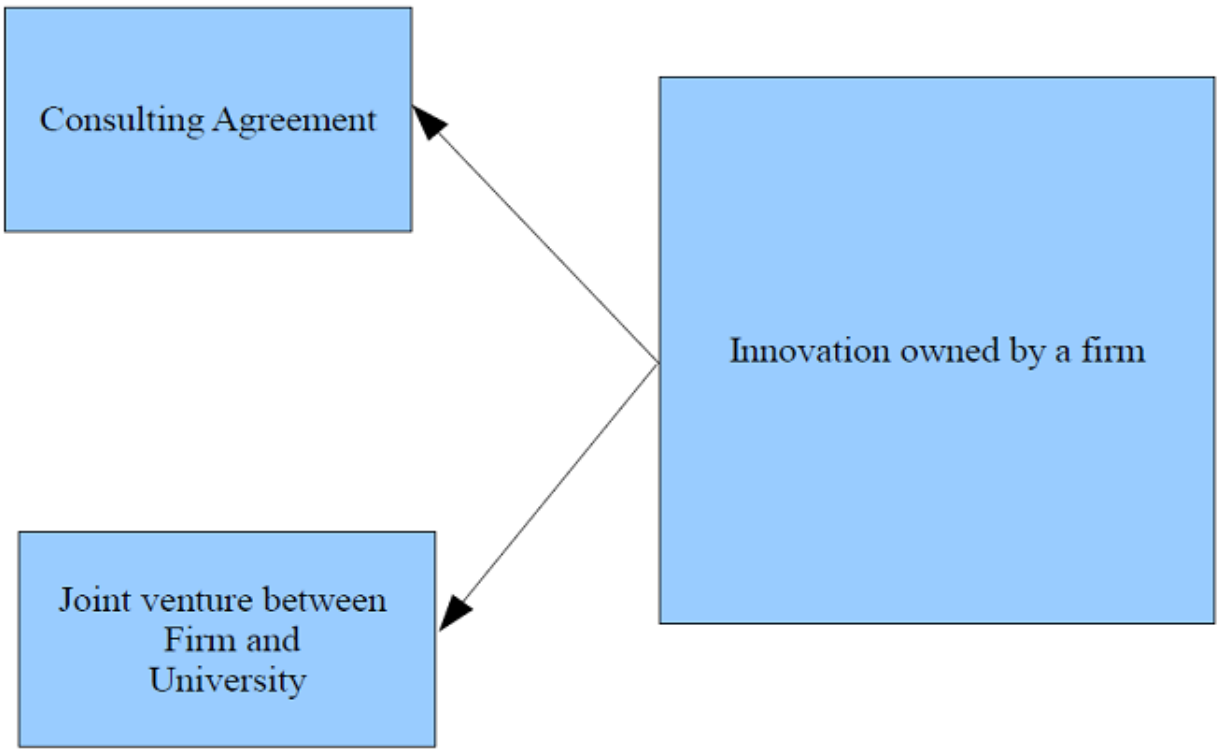


FIGURE 4A
INWARD MODEL



Source: Author

CONCLUSION

Universities are often instrumental in the development of NTBFs. In many instances innovation birthed at universities is spun-off into new firms, and in many instances universities are instrumental to the development of technology germinated by non-spin-off NTBFs (Powell and Owen-Smith 1998; Perkmann and Walsh 2008). For these reasons, and because so little is known on technology based entrepreneurship, it was important to overview the literature on the topic. This paper has highlighted that universities are a major source of innovation; there are three main ways that universities disseminate innovation to industry; and academics have varying motivations for engaging in entrepreneurship. What is not so clear is the effect of VC on academic entrepreneurship. The findings on this are contradicting. A second grey area is how industry engages universities. The literature discusses licensing but does not provide depth on how this happens, or any depth on how NTBFs engage universities for contract services. Closely related, the literature fails to look at how universities are a source of CAs – specifically R&D CAs.

This paper has identified a number of gaps in the literature on academic entrepreneurship. The gaps identified in this paper can be used as a basis for future studies. Another major contribution of this paper is exposing the overall lack of knowledge on technology based academic entrepreneurship. Business and innovation activity around universities is having a profound effect on NTBFs, yet this paper has clearly shown that little is known about technology based academic entrepreneurship. It is evident that academics and policy makers need to invest more time in researching this topic. The inward and outward model of university innovation engagement offered in this paper provides a good framework for examining the knowledge gaps in technology based academic entrepreneurship.

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