Agricultural Technology Commercialization to Entrepreneurial Startups: Case study on Networking

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Abstract— Technology commercialization from public research universities provide impetus to startups with know-how that have a potential to succeed in the market. We examine a network-based incubator, in an agricultural research university, that supports the development of startups. Our study explores networking and technology commercialization support utilized by the incubated startups. We examine the mechanisms of network formation in a university-based incubator and distinguish the entrepreneurial and university networks formed. From the study, we develop a set of propositions relating outcomes at the startup level with entrepreneurial affiliation, experience, institutional incentives considering the local contextual factors. Using these, we derive managerial and policy implications for the stakeholders looking at diffusion of university developed technologies. The study explores the black box of entrepreneurship support, and provides appropriate strategies to technology commercialization with agri-tech startups. The study has implications to universities that support entrepreneurship formally and informally.

Keywords— technology commercialization, networks, incubation, entrepreneurial ecosystem, startup

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1. Introduction

One of the key inputs for startups is technology. Entrepreneurs rely on new technology, source their innovation from universities to emerge and grow startups, thereby creating wealth, and jobs (Bala Subrahmanya 2017). Universities that develop these technologies adopt various forms and processes of commercialization to achieve a variety of objectives. Of late, considerable interest has developed among scholars to understand the benefits and challenges of universities to support startups (Gerbin and Drnovsek 2016). Universities commercialize technology through various organizational forms (like incubators, research parks, Technology Transfer offices, among others), and arrangements (like consultancy, alliances, joint ventures, among others) to do transactions (like technology licensing and transfer, among others) on intellectual property (Phan and Siegel 2006a). Among these organizational forms, incubators have gained prominence over the last few decades to encourage entrepreneurship through new startup emergence, development and growth (Mian, Lamine, and Fayolle 2016).

We can view such entrepreneurship as an embedded phenomenon where social relations are facilitated by the linkages between entrepreneurs, resources, and opportunities (Jack and Anderson 2002). University-based incubators provide various support services including networking within the university and externally with investors, mentors and partners. Such a networking paves way to access and leverage resources and capabilities (Scillitoe and Chakrabarti 2010). Even while technology forms a key input to startups, networks that are formed around the university plays a key role in venture development.

We explore networking at incubators, affecting the emergence and development of startups and thus aiding technology adoption and diffusion. We examine the case of an agricultural research university incubator, where there has been a significant number of startups emerging and developing through technology commercialization and utilizing networks nurtured by the university. Our contributions are (a) identifying key relationships connecting scientist level incentives on IP based development and network engagement and (b) how entrepreneur experience is associated with type of resources garnered and recognizing opportunities through the networks developed.

The rest of the paper is structured as follows. Following this introduction, we provide background literature on networking in the context of entrepreneurship support, with a focus on startup level processes and outcomes. We then briefly provide an outline of the national knowledge system of agriculture to situate the study context. We then detail the case study method adopted, followed by a comparative analysis on networking among the sampled entrepreneurs. From this analysis we develop

a set of propositions, leading to certain implications on nurturing networks in entrepreneurial support ecosystems.

2. Networks in an entrepreneurial ecosystem

Mason & Brown, (2014) defined an entrepreneurial ecosystem as “a set of interconnected entrepreneurial actors, organizations and processes...which formally and informally coalesce to connect, mediate and govern the performance within the entrepreneurial environment”. Vogel & Fischler-Strasak, (2014) proposed that an ecosystem constitutes, "an interactive community that is composed of varied and interdependent actors and factors that evolves over time and promotes new venture creation". These definitions indicate the importance of the role of networking in ecosystems. Networks perform several functions like access to resources including finance, and support that are not easily accessible otherwise. The evolution of incubator models globally shows us that providing networking as a service was seen as early as the second generation of incubators (Allen and McCluskey 1990; Peters, Rice, and Sundararajan 2004; Mian, Lamine, and Fayolle 2016). Thus it is important to understand the role of networking and importance of social capital and trust in entrepreneurial activities (Bøllingtoft and Ulhøi 2005). Firstly, we look at the formation of networks in an entrepreneurial ecosystem. Secondly, we look at literature for studies on networking in various perspectives viz. roles played by various actors in the process of networking and the characteristics of networks and the downstream impact on the performance of incubated startups.

2.1. Forming and sustaining networks in incubators

Bøllingtoft & Ulhøi (2005) proposed a hybrid networked incubator model that took advantage of territorial synergies, relational symbiosis and economies of scope. They further indicated that mechanisms at an individual level and mechanisms at the organization and social environment level affect startup development. Later studies indicated that the geographical concentration and agglomeration only partially explain the different levels of entrepreneurial activity at community level (Minniti 2005). Incubators take different strategies to nurture relationships which include on-boarding mentors and specialists, accrediting investors and building market linkages. Incubator's networks can be internal or external (Soetanto and Jack 2013). The internal networks tend to form relations with fellow incubatees or within the university where the incubator is located, whereas external networks tend to form relations with customers, partners, investors, among others (Apa, Grandinetti, and Sedita 2017). Networks can be sustained by formal and informal relations and can play roles in innovation

development (Rothschild and Darr 2005; Smilor 1987). Thus creation and maintenance of networks can strengthen the incubation process (Patton, Warren, and Bream 2009). Such networks have distinct characteristics, and it is appropriate to look at some of the characteristics from social network theory.

2.2. Characteristics of networks

Social capital studies distinguish networks based on the strength of ties in the network, heterogeneity of networks, and roles of actors in a network. Strength of ties depend on level, frequency and reciprocity of relations between actors in a network and varies from strong to weak ties (Aldrich and Catherine 1986). Strong ties tend to develop through trust over a long period of time typically within a well-defined group, whereas weak ties develop as connects or relations between different groups (Granovetter 1977). We can expect incubators to nurture strong ties among peer startups and within the university level, while mediating weak ties externally. This makes the incubator a broker in a network, filling in the gaps of the entrepreneur's network as a boundary spanner (Bergenholtz 2011; Peters, Rice, and Sundararajan 2004). Further, the notion of community of practice among incubated startups is also gaining prominence in the relational context. The quality of incubator network was found to depend on three factors, namely, strength, health of identity and the quality of boundary space (Theodorakopoulos, K. Kakabadse, and McGowan 2014). Another key characteristic is heterogeneity that characterizes identity of network actors. Identity may be defined with gender, background, affiliation, roles, among others. Professional associations tend to be homogenous networks with actors of similar identities. Considering the number of stake holders involved in a university-based incubator, heterogeneity in relations can be expected (Mian 1997).

Network heterogeneity may also arise from the arrangements of actors around an activity like technology commercialization. Markman, Siegel, & Wright, (2008) provided a categorization of internal, quasi-internal and externalization approaches to technology commercialization activities. Here internal approach concerns with activities that are within a firm or a university, quasi-internal approach concerns with structures like an incubator promoting entrepreneurial companies, and external approaches concern with activities that are outside of a firm/university but within clusters or in spin-off firms. The roles played and activities supported by internal, quasi-internal and external approaches may overlap and the modes of commercialization may span across more than one approach as well. Even though the approaches may have differences in objectives, approaches and processes, they all rely on the relational context to nurture effective technology commercialization.

2.3. Outcomes of networks

The impact of networks can be seen at different levels of outcomes. For example, at the entrepreneurial ecosystem level or at an university level where networking can help commercialize research output, or at an incubator level where networking can help mediation for resources. At a startup level, networking can have impact at different life cycle stages in resource garnering and growth (Eveleens, van Rijnsoever, and Niesten 2016). University incubators nurture networking for two types of benefits, tangible or intangible. Tangible benefits include resources like financial capital or physical assets, whereas intangible benefits include intellectual property, skills/capabilities and reputation, among others (Soetanto & Jack, 2013). Universities and incubators play a key role in enabling networking for knowledge flows to incubated startups. The downstream impact of such networking on startup performance has been studied from multiple angles. These studies include examining the probability of success over failure and improved organizational performance of the startup against factors like absorptive capacity of firms, and nature of linkages like licensing and faculty relations (Rothaermel & Thursby, 2005b, 2005a). The study of networked incubation should consider, firstly, the context of the national knowledge system level and, secondly, networking mediation efforts at the university level.

Given this, it is appropriate to understand the agriculture knowledge system in a developing economy which includes a network of universities. These universities collaborate and commercialize technologies developed with private industry partners including entrepreneurs to achieve mission objectives. Technology commercialization mechanisms are important starting points for diffusing technologies in a given intellectual property regime of a region. Technology diffusion relies on network links and interconnectedness in the context of an innovation and its use (Rogers 2003). Against this backdrop, we consider the broader agriculture knowledge system in India and its network structure as well as the processes adopted to nurture networks.

3. Background context of the study in India: National Agriculture Knowledge System

We provide a brief overview of the study context in India, covering the national knowledge system relevant for agriculture.

3.1. IP regime in India

The start of a formal IP regime in India can be traced back to 1995. In 1995, the World Trade Organization introduced a multilateral legal agreement called the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) that set minimum standards for regulation including provisions, enforcement, and dispute resolution in such intellectual property rights by member nations (ICAR 2006). The intellectual property types covered in TRIPS also included plant varieties and geographical indications that are common in agriculture. India, being a member of WTO with its trade enticement, became a party to TRIPS agreement from 1995. This can be considered the starting point for the establishment of an IP regime in India at the level of international standards. In addition to the regulatory standards, TRIPS recognizes as part of its objective that the “protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology” (WTO 2018). National level analysis from the National Knowledge Commission (NKC) was tasked to create a blueprint for tapping the knowledge bases in the country to face 21st century challenges (Commission 2009). NKC emphasized the agriculture crisis with respect to the dependence for jobs and GDP contribution and diminishing income growth for farmers. Further NKC recommended concrete steps across both knowledge generation and knowledge application. The knowledge generation step had suggestive actions like modernizing, organizing and coordination for better research outcomes in specific areas, appropriately incentivizing research and exploiting Intellectual Property Rights and encouraging private sector participation. The knowledge application step suggested farmer and community led collaborations with universities, and a decentralized Agriculture Technology Management Agency that can be both participatory and responsive to local needs among other actions (Commission, 2009).

The Department of Agricultural Research and Education under the Ministry of Agriculture is one of the arms that governs the Indian Council of Agricultural Research (ICAR) that coordinates research and education on agriculture across the country. ICAR is the apex body of the National Agriculture Research

System and it is one of the largest in the world. ICAR coordinates, guides and manages research and education in agriculture across its 101 institutes and 71 agricultural universities in India. Its mandate and vision indicate commitment to national priorities on food security and engages in cutting edge research across various areas related to agriculture. This, makes it both a generator and an enabler of application of agricultural science and technology knowledge through its network. ICAR clearly recognizes the role of various stakeholder engagements for technology knowledge dissemination and commercialization (ICAR 2011). ICAR had released its Intellectual property guidelines document back in 2006 (ICAR 2006). This document established the general policy framework for IPRs, procedures adopted for management across the portfolio of different types of IP, incentives for scientists and related human resource development for IP related expertise. Notably the policy also paved way for public-private partnerships for IP commercialization through several technology management organizational arrangements at headquarter, zonal and university levels. These departments were subsequently established nationwide across most of the ICAR institutes (ICAR 2020).

3.2. National Agricultural Innovation Project

Based on the need to nurture and support development and application of innovation in agriculture through collaboration with farmers, public-private partnerships and broadly the civil society, the National Agricultural Innovation Project (NAIP) was envisioned and implemented by ICAR. The project had specific objectives on catalyzing change, encouraging innovation diffusion with market orientation, among others. The project supported by the World Bank provided an opportunity for ICAR to standardize and regulate the vast amount of research output that can be commercialized through its institutes. The project's objectives were broad, and it reoriented the National Agriculture Research System (NARS), enhancing research in outcome-oriented areas like productivity, employment, livelihood and income, and building capacity to undertake research in frontier areas of agriculture. The project, biggest ever in agriculture innovation system, was completed over the period 2006-2014 giving an impetus to progressive policies, infrastructure, agricultural extensions and technology diffusion from the universities of ICAR. These included consortia mode of research, public-private research partnerships, technology commercialization that is decentralized and providing business development and incubation across ICAR institutes (World Bank 2015). Twenty-two business planning and development units (BPDU) were created providing market linkage, incubation and entrepreneurial support across the universities. The World Bank project appraisal and independent review estimated that these BPDUs and market linkages provided support to more than 1200 entrepreneurs and 91 new agri-business initiations and

substantial job creation. Further 9700 farmers benefitted from direct technology transfer through demonstrations and spontaneous adoption (World Bank, 2015a). During the same period, there has been a considerable increase in the level of IP protection across ICAR institutes (Suman and Pandey 2014). This initiation may be considered a logical starting point for establishing incubator organizations in agricultural universities that have now proliferated across the country.

Thus, given a national level knowledge system with networks across and within universities, extension organizations to farmers and collaboration with both government and private sector provides an appropriate context for our study. The networks nurtured by these universities are through their government interfaces, commercialization, outreach and incubation arms.

4. Materials and methods

Indian Institute of Horticulture Research (IIHR) is one beneficiary of the NAIP and subsequent IP policies that came into effect across ICAR institutes. We selected IIHR as our case to examine networking in a technology commercialization context. IIHR was established in Bangalore in 1967 and is the largest Institute in South and South East Asia engaged in research on all basic and applied aspects of horticulture. It has 200+ scientists with expertise in diverse disciplines. The institute comprises necessary infrastructure as production capacity, research facilities and labs. It currently holds 150+ IPRs across the thematic areas of plant varieties, plant health management, post-harvest technologies, biotechnology products and services and farm implements (Mysore 2015). The patent portfolio of IIHR is concentrated on bio-agents and implements/designs. In its effort to promote public-private partnerships, the institute offers a plethora of activities including consultancy, networking, training, on-site incubation, testing and analysis services and information services (ICAR 2019). IIHR case is rich in information about the phenomenon of technology commercialization and is ranked among the top IP holders in the country (IIHR 2018).

The incubator was set up as an arm of the technology management unit, which is unique to IIHR, as against the common organizational set up of separating technology licensing and incubation functions. The incubator provides services for scaling up lab scale technologies that are licensed in 2 different modes viz. onsite and offsite. In both the models, entrepreneur licenses brands and agricultural technology products, along with know-how through a structured licensing process. The incubator nurtures networking and close collaboration with the scientists who have developed these technologies. Such consulting services help scale up both production and marketing through the university's infrastructure and network. In the onsite incubation model, the entrepreneur gets the infrastructure

including labs, production facility and office space. In addition, the onsite incubatees are allowed to sell their products through the market linkage provided at the university. This linkage accounts for a large proportion of sales for many startups. Specialized consulting, technology trials, collaborative research and IP related services are also available for the entrepreneurs. We situate our study in the intersection of technology commercialization and network-based incubation. Our research interest lies in the mechanisms of network formation, and the outcomes from such networking. We examine the following question, “How do agri-technology entrepreneurs leverage networks for startup development?”.

Qualitative methods are preferred when empirical evidence and theories are lacking (Phan and Siegel 2006b). Our research process will follow the widely accepted flow for case-based research, starting with crafting of a conceptual framework and set of questions for collecting qualitative data (Yin 1994). This is followed by field work interviewing the stake holders and collecting data. Further this was substantiated by secondary data sources across the associated universities’ web sources. We then performed a within-case analysis familiarizing with the processes before presenting our causal framework that is based on the evidence collected (Eisenhardt and Graebner 2007). The data sampling for this research was purposeful, given the variety of stake holders and the complex processes involved. Such a sampling is acceptable as the phenomenon of technology commercialization and the network-based incubation together is both an extreme case and openly observable (Atkinson et al. 2003). Table 1 shows the significant level of technology licensing at IIHR sustained over a decade. From these startups we selected a sample of four, and each startup is represented by one founder entrepreneur, who we interviewed. These entrepreneurs had several distinguishing characteristics on entrepreneurial experience, university affiliation, and network reach.

<<Table 1: Licensing / technology commercialization at IIHR Bangalore near here>>

We developed and used a case study conceptual framework (Figure 1) and a set of initial questions for the in-depth interviews. In this conceptual framework we begin with the entrepreneur (first class of respondents) who derives specific knowledge, and networking support from the university’s stakeholders (second class of respondents). These university stakeholders include the scientists, technology manager and the incubator manager. While there was opportunity to include other university and ecosystem level stakeholders into this framework, we have retained only the network actors in incubation (Clauss, Moussa, and Kesting 2018).

<<Figure 1: Conceptual framework for the Case-Study Source: *The Authors* near here>>

The data collection involved interviewing the following stake holders:

- 1) Entrepreneurs: This group represents both prospective and existing entrepreneurs who have interest to build agri-innovation startups based on the technologies developed at the university.
- 2) Principal Scientists: This group includes investigators who are IIHR employees with advanced degrees and are researching in specialized horticulture areas, developing new technologies and innovations and testing them at lab scale.
- 3) Institute Technology Management Unit (ITMU): This unit is the university's formal structure that is tasked with technology protection, licensing and generating incomes based on the IP developed by the scientists.
- 4) Incubator Management: This is a quasi-structure internal to the university, and a separate non-profit organization that markets the innovations and supports developmental needs of the entrepreneurs.

We conducted face to face / telephonic interviews with the stake holders from December 2018 to February 2019 (Table 2). The unit of analysis is the licensee viz. the entrepreneur, who has licenses out an IP / know-how from the university (Wright, Birley, and Mosey 2004). The licensees are embedded in the university or the entrepreneurial support ecosystem through specific arrangements like the licensing contract or the incubator service agreement.

<<Table 2: Summary of interviews conducted near here>>

5. Network formation in incubation

We identified two classes of networks formed namely university networks and entrepreneurial networks, indicating the origin of the network. University networks are the ones that are initiated and maintained by the university, whereas the entrepreneurial networks are the ones nurtured by the entrepreneur. These networks are also distinguished by their varying degrees of formalization that can be measured by the age and the role of the network initiator. University networks are supported broadly within the national innovation/knowledge system through collaborative formal arrangements among the network players including governments and extension mechanisms established for farmers. Whereas entrepreneurial networks rely on the trust base developed by the entrepreneur or the startup to develop and sustain.

5.1. University networks

The university is part of agricultural universities network across India under ICAR. This enables the university to remain focused on its primary mission objective and yet actively collaborate with other universities. Such a focus translates into investments across both human capital in attracting high quality researchers in the field and physical capital in building necessary infrastructure to conduct research. IIHR built its core infrastructure since inception from 1970 till 1990 when it established several key divisions for basic and applied research, primarily focused on improving yield of crops. More recently the institute has been focused on supporting and developing new technologies for sustainable horticulture improving livelihood and nutritional security.

The institute set up an Agriculture Technology Information Centre (ATIC) as a communication channel for disseminating information and technologies developed at IIHR and also serving as a sales channel for onsite incubatees. This is a key network enabler as it brings the end users, namely, farmers to the institute for seeds, plant varieties, agri-inputs and implements. Business Planning and Development Units (BPDU) serve as another network extension created through the NAIP project which provides an interface between end users and entrepreneurs.

The second networking intervention is provided through Krishi Vigyan Kendras (KVKs; which means Agriculture Science Centers) which are extension units at the district level to provide support to farmers on testing, training, and crop related services. IIHR currently supports two such KVKs covering two districts in Karnataka, viz. Kodagu and Tumkur. KVKs provide the end point interface in the network with farmers to access IIHR's localized technologies and know-how for crops grown in the region.

The third networking activity that IIHR enables is through entrepreneurship development programs (EDP) for emerging agri-entrepreneurs. In these programs the principal scientists introduce a set of technologies developed at IIHR to potential entrepreneurs. These programs provide information regarding the technologies and also give estimates on investments needed for implementation, depending on the needs. Further principal scientists take this opportunity to develop network among farmers and also connect them to the local KVKs or other extension units. In addition to these (prospective) entrepreneurs, large agri-input companies also approach IIHR for technology to commercialize them in the form of products.

Together, these interventions develop and maintain the conditions for both emergence and development of incubated startups. One startup emerged after attending the entrepreneurship development program and obtained the required technology license to commercialize. While the startup has grown since then, it continues to source critical inputs that is produced at the university. The experienced co-founders were able to leverage their personal network for raising financing and setting up their own manufacturing facility.

One entrepreneur began the startup after gaining confidence from the experience he had in setting up university developed solutions for farmers during his PhD duration. This experience also led to broadening network relationships at farmer level. The same experience helped gain insights into what products may potentially suit the target markets. First time entrepreneurs chose safe bets on technologies to license, particularly those that already have established a market presence. The influence of peer group in such a decision making was noted in one case. Thus, affiliation provided certain trigger experiences that has shaped the entrepreneurial trajectory. Reliance on scientists for business leads was common among both experienced and first-time entrepreneurs.

5.2. Entrepreneurial networks

The entrepreneurs relied on various networks for their startup development. These networks had specific outcomes like product development, sales enablement, knowledge and access to financing. Across our sampled entrepreneurs, the startups were in different stages of formalization of networks for production or product development. The type of network included supply of raw materials or specific manufacturing expertise that is nurtured for specific needs with long term arrangements. Some of these networks are not local and required long time to develop and formalize over the lifetime of the startup. Two of the sampled entrepreneurs have built relationships with the farmer community for supplying raw materials.

As startups grow, sales and distribution become critical for scaling up. Here we saw experienced entrepreneurs taking very specific steps to build dealer network across the country and develop formal distribution networks with other sales channels. Early stage and first-time entrepreneurs in our sample did not show indications of having formal sales and distribution network. Experienced entrepreneurs were assertive in building sales networks, in one case through retail showrooms and in another case through dealers. Further, such an assertive behavior was noted in seeking pre-commitments or policy changes that concern their business. The university provided opportunities in forums where such representations can be made by the entrepreneurs. Entrepreneurs who took up licenses of technologies relied on their relationships with the respective principal scientists who were experts in their domains. If an entrepreneur licensed more than one technology, they tend to have relationships with several scientists across different departments. As entrepreneurs continue to develop the technology, specifically technology /functional characteristics, they continue to take valuable technical advice from the scientists.

As for funding access through entrepreneurial networks, experienced entrepreneurs had better success in raising funds from venture capital funds than first time entrepreneurs. One entrepreneur indicated importance of familiarity of the venture capital firm with the nature of business for both synergies and reasonable expectations on the growth prospects of the business. Among early stage startups, at least one entrepreneur was able to access government grant through an open competition. Such grants serve as an important signaling for further funding access through other formal sources specifically venture capital funds, and therefore could be seen as an important network lever.

5.3. Outcomes of incubator networks

In summary we can look at both the university and entrepreneurial networks based on the activities and outcomes achieved (Table 3).

<<Table 3: Networks of Incubator: Activities and Outcomes near here>>

6. Results and discussion

From our analysis we see that various networks and interactions form an important element of the university entrepreneurial ecosystem. We can evaluate the strengths and weaknesses of such an ecosystem at network level, by examining the characteristics of existing arrangements and norms used in the ecosystem (Inkpen and Tsang 2005) (see Table 4). These characteristics can include the level of

governance in the network, formation of network ties, strength of such ties, goal orientation and level of trust among the network participants.

<<Table 4: Network strengths and weaknesses near here>>

At the university level, high trust networks are formed between startups and the principal scientists. There is substantial level of goal alignment (around technology diffusion) between the startups and the university objectives. One scientist clearly indicated that the university considers startups a viable commercialization strategy and it is helpful to have an attractive incentive structure. Whereas the entrepreneurs trusted the scientists due to their experience in the field and having a ready advisor particularly resolving issues during product development. Although the university is part of a larger network of universities, broader portfolio of innovations from other ICAR universities were not opened up for licensing to startups. This is important for entrepreneurs who consider increasing their product/service scope.

Although sales at the Information Center is limited, it provides the much-needed relational capital for the startups in finding and retaining key customers. But the farmer extension centers run by the government and supported by the university are under-utilized, even while providing a scale potential for technology diffusion. This may be attributed to entry barriers at the extension centers. Experienced entrepreneurs were aware of these issues and solutions including the market-mechanism based product selection adopted in extension centers in other states. Further, these entrepreneurs were advocating for such mechanisms in governmental interactions enabled by the university.

All the entrepreneurs in the agri-input business asserted that building dealer level network was hard. The entrepreneurs identified dealers as critical network actors who provide the last mile interface with farmers. Dealers provide marketing, advice, sales and services for the products. Dealers influence the farmers and directly affect the cost of cultivation. Thus, creating an efficient dealer network can encourage diffusion of innovative products. But the university objectives are incongruent with dealer objectives i.e. while the dealer aims at maximizing profits/commissions at a product level, the university is only interested in diffusion of cheaper effective technologies.

Vertical linkages in the network require specialization and integration with other suppliers into the startup's product development, testing, and manufacturing. The suppliers may include partner or sub-contractor networks that are useful for startups. Experienced entrepreneurs were able to leverage vertical linkages better by both broadening their reach and deepening the nature of relations with suppliers than first-time entrepreneurs.

Principal scientists due to their role, have provided both advisory on technology commercialization and network mediation to prospective customers to the startups. This may be partly attributed to the incentive structure that the scientists have with respect to technology commercialization and the disincentive that they cannot venture out themselves. Further, the scientists were acutely aware of the policy developments and were part of committees that advised the government on key issues with respect to achieving national mission targets on increasing yields and farmer income. These lead us to the first set of propositions as shown in Figure 2.

<<Figure 2: Scientist incentives-technology diffusion propositions Source: The Authors near here>>

Experienced entrepreneurs were more assertive in creating and leveraging networks, garnering funding sources, and having clear focus on marketing. This seems to happen over a long period of time as trust relationships develop both through their field experience. Thus, they can attract investors, collaborate with scientists in other universities, and attract qualified employees. Whereas first time entrepreneurs who lack such a network access, face significant hurdles in building the first version of the product, or marketing to a larger customer base. Among the entrepreneurs, those who had networks in their home markets and beyond, were more likely to develop innovative products / services and also garner sufficient growth capital. These factors lead us to the second set of propositions as presented in Figure 3.

<<Figure 3: Entrepreneurial experience-resource garnering propositions Source: The Authors near here>>

Affiliation with the university aids entrepreneurs to navigate networks across departments and institutions. In addition, it also provides the required legitimacy to the startup and a shared identity to the entrepreneur. These in turn encourage active engagement with these diverse network actors. We hence derive the third set of propositions that lead the entrepreneur to recognize opportunities while being embedded in the university ecosystem and its network (Figure 4).

<<Figure 4: Entrepreneur affiliation-opportunity recognition propositions Source: The Authors near here>>

These propositions developed from our study indicate that networks play a multi-dimensional role in the development of startups in an incubator, thereby contributing to its faster emergence.

7. Summary and implications

We have examined the technology commercialization and networking-based incubation at IIHR, an agricultural research university in India. We note that technology commercialization has provided some

fillip to the emergence of agri-technology startups and this is important for an emerging economy like India where agriculture sector is critical for the economy. But for further growth of the startups, networking support from the ecosystem is essential. We studied the entrepreneurial support ecosystem in providing networking-based services around technology development, resource garnering and market linkages. From the startups compared and studied we derived a set of propositions on the antecedents and effects of networking on startup development. We noted that entrepreneur, university characteristics affect business outcomes at startup level and mission outcomes at a national level.

We can derive certain managerial and policy implications based on our findings at the entrepreneurial support ecosystem and the incubator levels (Theodoraki 2019). While the incubator remains a key element within the entrepreneurial ecosystem, its influence is limited to its networks. At IIHR, the networks were internal to the university and externally it included the government and sector. Existing mediation efforts of universities could be further strengthened by looking at pools of IP across universities for potential commercialization. University can scale up and formalize events including fairs, exhibitions and provide exposure of available technologies to entrepreneurs. Further forums may be created to deliberate necessary policy/structural changes in consultation with scientists, farmers, policy makers, experienced entrepreneurs and investors in the mix (Garud, Gehman, and Giuliani 2017).

Policy objectives on technology diffusion at various levels (policy, crop, department, university levels for example) could be driven by startups and integrating them with the farmer extension networks. Progressive approaches to support deeper market linkages for startups to this end is possible especially where the universities support the extension centers. One potential way could be by opening up the extension networks as sales and delivery channels for entrepreneurs, to list, compete and sell university technology commercialized products.

Being a qualitative study, the results of the study are not generalizable. The entrepreneurial ventures are either one person companies or partnerships. Due to a dearth of secondary data it is difficult to compare lifecycle progression and other growth metrics among startups. Specific studies on the characteristics of networks at an entrepreneur level may lead to better understanding of the trust relations necessary for acquiring human and financial capital. The strength of such networks at a university level may affect the mediation outcomes of incubators and technology management organizations, such studies require more granular data.

Table 2: Licensing / technology commercialization at IIHR Bangalore

Source: Commercialization of Horticultural Technologies Leaping Ahead ICAR-IIHR Bangalore India (2018).

Year	Number of technologies licensed	Number of licensees
2008-09	05	09
2009-10	07	22
2010-11	28	52
2011-12	26	59
2012-13	16	42
2013-14	41	101
2014-15	26	80
2015-16	28	64
2016-17	29	48

Table 2: Summary of interviews conducted

Respondent type	Respondent experience	Primary role of the respondent
Entrepreneurs	PF1 (10 man years) NP2 (6 man years) GP3 (4 man years) LB4 (2 man years)	Technology (products/services) and business development
Principal Scientists	MSR (40 man years) SK (20 man years)	Technology research and development within IIHR
Institute Technology Management	SM (30 man years)	Licensing and IP protection of IIHR developed technologies Economic impact analyses of the diffused technologies
Incubator Management	KR (5 man years)	Incubation support for startups

Table 3: Networks of Incubator: Activities and Outcomes

Type of network	Activities	Outcomes
Information center	University information dissemination and sales extension	Awareness on new developments and sales of products for startups
Principal scientists' network	Advisory network of scientists and provides an interface between the farmers and (prospective) entrepreneur community	Venture emergence, Technology and business investment advice to startups
Agriculture Science Centers and extension network	Government information dissemination and end point services and testing of new developments at farmer level	Awareness and adoption of new technologies
Dealer network	End point sales and service for farmers	Sales and delivery channel
Funding network	Access to funding sources and evaluation of startups	Financial capital access
Supplier network	Formal relationships for specific manufacturing, and sourcing	Inputs for products, Product development and manufacturing

Table 4: Network strengths and weaknesses

Network	Characteristics	Strength	Weakness
Information center	Structured; Loose tied; Easy to form; Congruent goals; High trust	Ready sales channel	Scale is limited
Principal scientists' network	Unstructured; Vertical; Close tied; Easy to form; Incongruent goals; High trust	Knowledge centric	Readiness of new technology applications is limited
Farmer extension centers	Structured; Loose tied; Hard to form; Congruent goals; Low trust	High level of access and scale	Low level commitment
Dealer network	Structured; Vertical; Close tied; Hard to form; Incongruent goals; Low trust	Scale and ability to service	Opportunistic; Difficult to build
Funding network	Unstructured; Horizontal; Close tied; Hard to form; Congruent goals; High trust	Access to finance	Difficult to build
Supplier network	Structured; Vertical; Close tied; Hard to form; Congruent goals; High trust	Access to raw material or niche sub-component producers	Difficult to build

Figure 5: Conceptual framework for the Case-Study *Source: The Authors*

Figure 6: Scientist incentives-technology diffusion propositions Source: The Authors

Figure 7: Entrepreneurial experience-resource garnering propositions Source: The Authors

Figure 8: Entrepreneur affiliation-opportunity recognition propositions Source: The Authors

Teaching note

Agriculture is highly technological in modern days. Agriculture contribution to GDP may be smaller when compared to manufacturing or services, but it still provides massive employment. Prospective entrepreneurs seek new technology to maximize yield and minimize input costs in agriculture. These technologies emerge from universities and research institutions that have resident specialized human capital and infrastructure. Entrepreneurs interface and embed themselves in such research universities through technology business incubators. Technology business incubators provide services for entrepreneurs to commercialize technologies that are a result of research activities at the university and also provide market access through their own linkages with farmers. In technology business incubation, networks of scientists, university, farmers and entrepreneurs all play a role in supporting the startup. It is thus useful to understand the nature of these networks and outcomes to improve the overall diffusion of new technology in agriculture.

The case analyzes the technology commercialization from an agricultural research university to entrepreneurial startups. Specifically, the context of an emerging economy particularly covering the intellectual property regime and the entrepreneurial ecosystem support that is available is given as background. We look at technology business incubator as the primary startup organization in addition to the university and its technology management unit. We concern ourselves with the nature of networks that are developed during incubation and show differences among ventures that we interviewed.

The case may be used for technology management, strategy and innovation, and entrepreneurship courses, where the role of networks are generally not covered in the context of diffusion of technology. Further, the case may inform students and practitioners on the nature of networks that need to be enabled and nurtured for getting better outcomes from entrepreneurship support.

Assignment questions may cover reflection of students on their current university to see what they can learn from the practices that are already being driven by the university formally and what happens informally. Students should be able to identify specific outcomes and objectives of networks and the processes through which they are formed. The teaching plan could follow the country specific policy context, university context and the support needs of entrepreneurs that may differ locally. Such context can be mapped to the case specific analysis particularly on resources, processes and causation related details. References that

cover both the theoretical and empirical coverage is provided in the case study along with sources of secondary data.

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