What is the core competence of academic entrepreneurs in research-based innovation? : the empirical study of academic reputation and technological depth

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Abstract. Knowledge base is a key determinate for improving innovation performance of a company. Hence, technological depth and breadth, two dimensions of knowledge base, have drawn wide attention by scholars in recent years. Many studies discussed about the significance of technological breadth in promoting absorptive abilities of enterprises, technological depth has proved to be more critical for the firms' creativity in their early stages. However, few researches studied on what could affect technological depth; therefore, the focus of this paper is to find out the most important factor which impact technological depth of firms. Based on the empirical data of 357 academic entrepreneurs from the opening of the NEEQ to the end of 2016, we figure out that academic reputation gives a significant positive influence on the technological depth of academic enterprises. Furthermore, this paper also finds that social capital owned by academic entrepreneurs has a moderating effect on the relationship between academic reputation and technological depth. According to our findings, academic entrepreneurs with high academic reputation would like to concentrate more on technological depth, that their company can better improve innovation and R&D as well as gain core competence in innovation in early stage. Since companies need more external resources while growing, this paper also implies that the influence of academic reputation on technological depth would be moderated by the effect of social capital.

1. Introduction

Many literatures have shown that knowledge is the most important resource for innovation development. Companies can form competitive advantages by leveraging their knowledge base [1] [2]. Based on the knowledge-based theory, firms' heterogeneous knowledge base leads to different innovative performances [3]. Therefore, the study of how to enhance knowledge base is prior for enterprises in gaining core competence [4]. According to [1], technological depth and breadth, two distinct dimensions of a firm's existing knowledge base, are significant in innovation performance, especially for research-based enterprises. Although many scholars highlighted the importance of technological breadth because of its direct impact on absorptive ability of companies in R&D process [5] [6], the importance of technological depth in radical innovation is underestimated. [7] stated the vital role of depth in a company's early stages: since firms need to increase the complexity of knowledge to promote creativity, the depth of knowledge should gain more attention in their early stage. In order to deepen the research in technological depth, this paper not only emphasize the importance of knowledge depth, but expands our research to study on the key factor that could affect the technological depth.

The core competence of companies comes from continuous innovation in technology. In the early stage of entrepreneurship, founders focus more on inner abilities by developing technological depth, thus they promote experience accumulation and research-based innovation through the continuous investment of intellectual assets and knowledge [8]. Academic Entrepreneurship is a

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series of business activities in which founders participate in technology commercialization [8]. Most academic start-ups are concentrated in high-tech industries, the abilities of acquiring and integrating internal and external knowledge, technology and resources are critical for their innovation and R&D process [9] [10] [11]. Academic reputation, a unique strategic resource only owned by academic entrepreneurs, is the most precious intellectual capital of the company. [13] demonstrated that academic reputation is the academy achievements and influence of academic entrepreneurs. By leveraging their advanced knowledge and know-how, academic entrepreneurs can gain more competitive advantages in technology development. However, few studies have provided detailed insights into the relationship between academic reputation and knowledge depth.

The purpose of this study is to offer an explicit study on the effect of academic reputation on technological depth. Specifically, this paper aims to clarify the definition of academic reputation and examine how academic reputation contributes to the development of technological depth. Furthermore, since knowledge is obtained both from inside and outside of companies [12], we also take social capital into account and test whether it has an impact on the relationship between reputation and depth or not.

The paper proceeds as follows. The following section provides the theory and hypothesis applied in this work. Section 3 describes the sample collection and research method. Section 4 is the data analysis and empirical results. In the final section, we summarize our findings and discuss the implication of our study.

2. Theory and Hypotheses

2.1 Literature Review

2.1.1 Technological Depth

According to the knowledge-based view, technological depth represents the vertical dimension of knowledge [2], it is defined as the internal technical knowledge that is consistently reused by the company [12]. [15] [16] described the depth of technology as the degree of cognitive difficulty a company has in analyzing the logical principles of something. [17] stated that technological depth is the degree of specialization of knowledge composition, which represents the quality of innovation. The deeper the technological depth is, the higher the achievement and sophistication of firms in their key field-in other words, the stronger the innovation ability in R&D process. Furthermore, [16] also proposed that technological depth plays an important role in the innovation process of companies. Regarding to [7], the role of technological depth is particularly prominent in the early stage of the enterprises: because of the limited resources and heavy pressure for survival, transforming technical knowledge into products is the vital in their early phase. Therefore, enterprises would like to concentrate their innovation on single technological field (depth) to sustain competitive advantages [13].

2.1.2 Academic Reputation

The definition of reputation has yet to be conclusively settled. There is a consensus that reputation is the total impression and evaluation of a person’s past behavior and characteristic by stakeholders [14] [15] [16]. Previous studies on academic reputation focused a lot on its impact on universities and research institutions. [17] found that good academic reputation could help people gain more recognition in labor market. [18] demonstrated that academic reputation is a unique

resource owned by academic entrepreneurs. It can make entrepreneurs strength their influence in certain technological field, thus help their company to get funding more easily. [19] linked academic reputation with academic researchers and entrepreneurs. Based on their research, academic reputation is defined as academic achievement and influence of academic entrepreneurs in a particular knowledge field. They also stated that the schools ranking and individual's academic reputation are the two dimensions of academic reputation. In this paper, we mainly refer to Lee's research on defining and assessing academic reputation.

2.2 Hypothesis Development

2.2.1 Academic Reputation and Technological Depth

[24] stated that there is a close relationship between technology strategy and knowledge assets of enterprises, [13] also found a significant correlation between intellectual capital and companies' performance. Founders with good education and rich R&D experience always leads to positive results of innovative activities. According to [20], university education significantly improved entrepreneurs' insight, imagination, and even social skills. The higher the level of education of managers, the stronger the absorptive capacity of organizations, as well as, the more creative and competitiveness of the companies [28]. Academic reputation is the academy achievements and influence of academic entrepreneurs. By leveraging their advanced knowledge and know-how, academic entrepreneurs can gain more competitive advantages in technological innovation [13]. Accordingly, we conclude that academic reputation is an important intellectual capital of academic entrepreneurs. That is to say, founders' academic reputation not only gives a positive impact on R&D investment and competition, but also on the innovation ability of companies [29].

Besides, [30] proposed that ranking of universities and research institutes has a positive effect on the success rate of technology transfer. [23] also stated that scholars from prestige schools have higher social recognition, so they can access more social resources and knowledge assets. Therefore, unversity ranking is another important component of academic reputation [31]. High ranking of academic entrepreneurs' schools makes entrepreneurs easily acquire cutting-age information and attract technical talents, hence facilitate R&D process. According to above, we proposed the following hypothesis:

H1: Academic reputation is positively related to technological depth.

H1a: The academic reputation of founder is positively related to technological depth.

H1b: The unversity ranking is positively related to technological depth.

2.2.2 Moderating Role of Social Capital

From knowledge-based view, knowledge is the most valuable resources in sustaining competitive advantages [21]. Technological knowledge, the scientific knowledge that applied to useful purpose, is especially important for promoting innovation [22]. In early stages, due to the limited resources and high uncertainty during R&D process, innovative activities of firms always concentrated on the technical filed they good at [23], thus technological depth plays key role at this time. However, since knowledge integration is vital in increasing technical expertise, firms need to collect various knowledge resources to maintain creativity and innovative ability [21] [12].Therefore, social capital, the interpersonal relationship and social network that enable entrepreneurs to obtain information, resources and money needed in the market [24], would become more important with the growing of firms. [25] proved that social capital is correlated to knowledge

acquisition. According to [37] [27], social capital is mainly consist of government capital and market capital. [38] demonstrated that social capital can help firms leverage external social network to obtain information, identify market opportunities and threats, as well as accelerate the speed of technological innovation. On one hand, social capital could foster the expansion of knowledge scope of companies, hence might moderating the impact of academic reputation on technological depth. On the other hand, researchers also found there is negative side of social capital that might hinder the development of companies. [39] [32] argued that over-reliance on policy-oriented resources and market resources would lead enterprises to focus on the short-term benefits, thus weaken their internal capacity building and impede their technological innovation. As a result, we make the following assumptions:

H2: Social capital moderate the relationship between founder's academic reputation and technological depth.

H2a: Government capital negatively moderates the relationship between academic reputation and enterprise technology depth.

H2b: Market capital negatively regulates the relation between academic reputation and enterprise technology depth.

3. Methodology

3.1 Empirical Setting: Academic Start-ups in NEEQ

In this paper, we select the data of academic start-ups from the National Equities Exchange and Quotations (NEEQ). NEEQ is the third largest stock exchange in China besides the Shanghai Stock Exchange and Shenzhen Stock Exchange. It is mainly aimed at SMEs driven by innovation. Moreover, unlike other stock exchanges, the NEEQ adopts the “registration system” that in line with international standards. Therefore, the data selected from the NEEQ have more research values and credibility [40].

Academic start-ups are enterprises focus on research-based innovation. The knowledge development and innovations play significant roles in establishing and sustaining their core competence [28]. Therefore, academic start-ups are served as the context to empirically test our proposed hypotheses. Listing on board means that a company has survived from its early stage and starts its growth phase. By studying the data from prospectus, we collected relevant data to analyze the relationship between academic reputation and technological depth, as well as test the moderating effect of social capital. In this study, we gathered the data of academic start-ups listed from the opening of the NEEQ to the end of 2016, that 357 academic start-ups with valid data were selected.

3.2 Data and Variables

3.2.1 Technological Depth (TD)

Technological depth, as the dependent variables in our study, refers to the extent to which a firm is specialized in a certain knowledge field. It is usually measured by the number of patents granted. Normally, a firm granted more patents in a certain technological field implies that it has developed deeper technology in this field. According to [43] [17], we quantized patents by calculating the IPC (International Patent Classification) code.

Before proceeding technological depth, it is useful to briefly mention the structure of the IPC

system. In the IPC system, there are 8 sections revealed by the first digit of the code (Expressed by the letters A-H). Classes are revealed by the first 3 digits, which are in turn divided into subclasses; and groups are revealed by the first 6 digits. An example is G06C7/02. In this example, G is the section that is covered under the heading of physics. G06 is the class (computing, calculating, counting) and G06C is the subclass (digital computers in which all the computation is effected mechanically). G06C7 is the group level and G06C7/02 is the subgroup level, which corresponds to keyboards. Patents granted in a NEEQ firm have several IPC codes. To calculate the depth measures, all IPC lists of the patents are utilized.

Therefore, we employed the measure of depth based on the number of IPC codes of patents from an academic start-up that is the same as the major technology field of the start-up itself. Formally, as an academic start-up works on I technology field, we set $\Gamma_{ij} = \{j \in I | x_{ij} = 1\}$ representing the IPC list of patent that is in technology field $j(j \in I)$and $x_{ij} = 1$ if the patent has an IPC code in field j. Then the depth of the technology field j is the sum of the depth over all patents in this firm:

$$d_j = \sum_{i=1}^{N} \Gamma_{ij}$$

Where N is the total number of patents from a firm. Thus, the technological of this firm is calculated as:

$$\text{Depth} = \sum_{j=1}^{I} \left(\frac{d_j}{N}\right)^2$$

3.2.2 Academic Reputation (AR)

According to [19], scholars' academic output and academic influence of the research institutions their worked in are highly related to academic reputation. Individual's academic reputation and university reputation are the two main factors that consist of academic reputation.

(1) Individual Academic Reputation: h-index

In this paper, we use h-index to measure the individual academic reputation. Professor Hrisch initially proposed h-index as the indicator to calculate academic reputation of scholars, and his method is widely accepted in researches in measuring individual academic achievements. According to [29], this index is based on the set of the scholars' most cited papers and the number of citations that they have received in other publications. The h-index of a scholar means that at most he has been cited at least h times in his articles. For example, if a scholar's h index is 30, the number of citations representing 30 published articles exceeds 30 [34].

(2) University Reputation: University Ranking (UR)

Normally, university ranking is an important method to evaluate university in its research excellence, social influence, specialization expertise, award numbers, industrial linkage, historical reputation and other criteria. [30]. Although the reputation of university is usually influenced by both overall ranking and professional ranking [25], in China, the overall ranking is more emphasized in evaluating university's academic reputation and social influence [30]). Consequently, in this paper, we measure the university reputation using university's overall rankings. We quantize

university ranking to 5-classes from international influence to Chinese local category, that represent 5 as world-class (Chinese universities ranked at US NEWS Top 100 University), 4 as project 985 universities, 3 as project 211 universities, 2 as the first tier universities, 1 as second tier universities and all others are assigned as 0.

3.2.3 Social Capital

[31] suggested that social capital is a tangible or intangible resource acquired by entrepreneurs during their communication in market. According to [32], four methods are mainly used in literatures in measuring social capital, namely name generation method, location method, social network resource method and capital input method. Since majority of researchers adopt the social network view in defining social capital [24], we also use the quantitative methods of [47] from the perspective of social network resources, and measure the social capital from two aspects: government capital and market capital. Specific methods are as follows:

(1) Government Capital (GC)

The government capital of entrepreneurs is measured by the network and resources gained by entrepreneurs when they served in government-relevant departments [47]. [34] stated that the working experience in banking or related trade associations helps entrepreneurs to accumulate certain social relations and capital. So we take the sequencing variable used by [34] to measure the government capital of entrepreneurs. Serving in government, banks, trade associations, state-owned enterprises (SOE) and research institutes are represented from 5 to 1. All other conditions are assigned to 0.

(2) Market Capital

[35] suggested that the founder's market capital can be evaluated from two aspects: the customers network (CN) and affiliation network (AN). The customer network is represented by the share of the top five sales customers. The higher the share, the smaller the customer network of company would be. The affiliation network is expressed by the number of units that the founder served in his affiliated enterprises.

3.2.4 Control Variable

In this paper, firm size, firm age, R&D intensity, debt ratio and industry are selected as the control variables. Specific method of calculating those control variables are proposed in Table 1:

Table 1. Control variable

Control Variable	Method
Firm Size (FS)	The enterprise size is the natural logarithm of the total asset.
Firm Age (FA)	The age of the enterprise is the year of the company's found to listing
R&D Intensity (RD)	$\text{R\&D Intensity} = \frac{\text{Expenditure on R\&D}}{\text{Prime Operating Revenue}}$
Debt Ratio (DR)	$\text{Debt Ratio} = \frac{\text{Total Debts}}{\text{Total Assets}}$
Industry (Ind)	Industries in biotechnology, pharmaceuticals, TMT ,R&D or manufacturing are assigned 1, as the remaining 0 [36]

4. Result and Analysis

Table 2 and Table 3 show the descriptive statistics and correlations for all variables. The results in Table 3 revealed that there is a significant positive correlation between technological depth and unversity ranking with correlation coefficients 0.18 (P<0.005). In addition, h-index has same positive correlation with technological depth that their correlation coefficients is 0.31 (P<0.005).

Table 2. Descriptive statistics

Variables	Min	Max	Mean	Std
Technological Depth (TD)	0.080563	1	0.480577	0.26884
University Ranking (UR)	0	5	2.380952	1.04154
h-index (HI)	1	44	22.42017	10.62684
Government Capital (GC)	0	5	1.966387	0.307201
Customer Network (CN)	0	1	0.501846	0.288438
Affiliation Network (AN)	0	7	3.140056	0.655566
Firm Age (FA)	3	24	13.71709	5.334967
Debt Ratio (DR)	0.043361	1.149894	0.619514	0.333667
Firm Size (FS)	3.762899	9.169312	6.533496	1.511835
R&D Intensity (RD)	0.001136	3.09101	1.547311	0.840491
Industry (Ind)	0	1	0.504202	0.500684

Table 3. Correlations, Note *** P<0.005,** P<0.01,*P<0.05,+P<0.1

Variables	1	2	3	4	5	6	7	8	9	10	11
TD	1.00										
UR	0.18***	1.00									
HI	0.31***	0.01	1.00								
GC	-0.01	0.07	0.14**	1.00							
CN	0.15**	-0.07	0.03	-0.05	1.00						
AN	-0.24***	-0.02	-0.11*	-0.13*	-0.14**	1.00					
FA	0.20***	-0.01	-0.06	0.06	0.03	-0.10*	1.00				
DR	-0.03	0.08	-0.03	0.02	-0.06	-0.01	0.01	1.00			
FS	0.15**	0.06	0.09+	-0.04	0.06	-0.01	-0.04	0.11*	1.00		
RD	0.14**	0.07	0.12*	-0.06	0.07	-0.01	-0.01	0.01	0.02	1.00	
Ind	0.14**	0.05	0.06	-0.02	0.10+	0.00	-0.05	-0.01	0.03	0.02	1.00

Table 4 shows the results of regression models examining the impacts of all variables to the technological depth. Model 1 uses control variables as the measurement of regression. Model 2 evolves the effect of independent variables versus dependent variables. Model 3 introduce the interaction term between technological depth and social capital. Overall, all regression models are significant (P<0.005). Control variables such as firm size, firm age, R&D intensity and Industry do have non-ignorable effects on technological depth as expected. However, debt ratio has no effect.

Table 4. Regression results. Note *** P<0.005,** P<0.01,*P<0.05,+P<0.1

	Dependable Variable:Technological Depth (TD)		
	Model 1	Model 2	Model 3
Firm Age (FA)	0.011***	0.011***	0.011***
Debt Ratio (DR)	-0.037	-0.033	-0.040
Firm Size (FS)	0.027**	0.019*	0.016+

R&D Intensity (RD)	0.044**	0.025+	0.018
Industry (Ind)	0.076**	0.057*	0.049+
University Ranking (UR)		0.045***	0.293**
h-index (HI)		0.007***	0.088***
Government Capital (GC)		-0.072+	0.246*
Affiliation Network (AN)		-0.071***	0.070
Customer Network (CN)		0.089*	0.011
GC*UR			-0.073*
AN*UR			-0.038*
CN*UR			0.022
GC*HI			-0.031**
AN*HI			-0.006*
CN*HI			0.002
R	0.328	0.515	0.552
R square	0.107	0.265	0.305
R square change	0.095	0.243	0.272
F value	8.452***	12.457***	9.331***

Hypothesis 1 predicts that academic reputation is positively related to technological depth. As revealed in Model 2, academic reputation of founders and university rankings are both positively related to technological depth. (β=0.007, P<0.005 and β=0.045, P<0.005). Hence, Hypothesis 1a and 1b are supported, that indicates Hypothesis 1 is fully supported.

Hypothesis 2 predicts that social capital moderates the relationship between founder's academic reputation and technological depth. While taking the interaction terms into Model3, it presents a significant proof that political capital negatively moderates the relationship between academic reputation (represented by university ranking and h index) and technological depth (β=- 0.073, P<0.05 and β=- 0.031, P<0.01), by which Hypothesis 2a is supported. Regarding to market capital, on one hand, it is clear that the network of customers negatively moderates the relationship between academic reputation (represented by university ranking and h-index) and technological depth (β=- 0.038, P<0.05 and β=- 0.006, P<0.05). On the other hand, the results also indicate the network of affiliated companies played less role in moderating the relation between academic reputation and technology depth that the corresponding regression coefficients did not reach statistical significance (P>0.10). Hence, Hypothesis 2b is only partially supported

5. Conclusions and Implications

The significance role of technological knowledge has been well established in past literatures. It was proved that technological depth is more crucial in the early phase of companies, especially for the ones driven by research-based innovations [7]. Though there is no doubt about the importance of technological depth, the studies on factors that can affect technological depth were rare. Hence, our research focus on this topic and try to fill in this research gap. Academic start-ups are mainly concentrated on high-tech industries. Their competitive strategies are highly relying on technological innovations [56] [9]. According to our empirical study of 357 academic startups listed on NEEQ, we found that academic reputation has a significant positive impact on technological depth, thus proving academic reputation is a critical competitive advantage as well as a unique strategic resources of academic start-ups.

To be an important intellectual asset, academic reputation represents the level of technological

achievement and cognition accumulated by entrepreneurs in certain knowledge and technology fields. It is heavily determining the ability of enterprises to commercialize the technical knowledge, hence positively influence the concentration of technological innovation.

However, our further study showed that social capital played a moderating role in the relations between academic reputation and technological depth. This is mainly because social capital would help company to access to more technological resources and knowledge, which consequently broaden the scope of technology concentration [57]. In addition, we also believe that by leveraging the benefit from government capital, companies might over-reliance on social policies, which consequentially hinder the development of internal capacity in innovation [58].

5.1 Research Implications

Our paper contributes to research in several ways. Firstly, the significance of technological depth for start-ups was neglect by scholars in previous research [7], our research tried to fill in this gap by highlight its importance in companies early stage and expand the research to study the key factor that could affect technological depth. Secondly, literatures about academic reputation were mainly talked about its impact on universities and research institutions, we clarify the definition of academic reputation and identify the two dimensions of academic reputation, which are school ranking and individual’s academic reputation [31].Furthermore, we also link the academic reputation to academic entrepreneurs as their unique intellect capital and offer a qualitative method to estimate the academic reputation.

5.2 Practical Implications

To understand the underlying relationship between academic reputation and technological depth has a vital impact in business practice. It is proved that entrepreneurs with good academic reputation can gain more competitive advantages in innovation because they are more sophisticated in research-based innovation and technology innovation. Nevertheless, although academic reputation is an important resource in enhancing technology concentration of companies, firms need to constantly acquiring knowledge from the whole society to maintain sustainable competitive advantages. Therefore, academic start-ups would more emphasize on social capital and diverse their technology field when they passed their early stages.

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