The Role of Venture Capital on Innovation in the Korean Biotechnology Industry

Byung Kuk Sohn and Kyung-Nam Kang

***Abstract*—Venture capital financing is generally considered as the most suitable external financing mode for New technology based SMEs, such as biotech SMEs. However, the way in which venture capital investments influence a firm's innovation performance is not as certain. In this paper, we empirically analyzed the impact of venture capital investments on networks and innovation performance in Korean biotech SMEs. Venture capital investment was positively associated with downstream partnerships, supporting Hypothesis 1-2 (β=0.29, p<0.001). Inter-firm collaborations were positively correlated with a firm's innovation performance, supporting Hypothesis 2 (β=0.18, p<0.10 in upstream partnerships, β=0.61, p<0.01 in downstream partnerships). This study showed the mechanism of venture capital investment influencing innovation by promoting downstream collaborations.**

***Index Terms*—Venture capital financing, biotech SMEs, downstream collaborations, innovation performance.**

I. Introduction

The biotechnology industry is one of the most important industries in a knowledge-based economy, whose development is important for national competitive advantage [1]. The development of the biotechnology sector is based on the emergence of a large number of small- and medium-sized enterprises (SMEs). The novelty and diversity based on the life sciences allowed the emergence of new firms [2] and the development of the biotech sector is based on the entry of a large number of small and medium-sized enterprises (SMEs) [3]. Many researchers focus on fast-growing SMEs as a key mechanism in the sector's development [3]. Biotech SMEs enter into linkages with external entities to acquire resources they lack such as finance resources. Poor access to external financing may limit the growth of biotech SMEs. In developed countries, venture capital financing is generally considered as the most suitable external financing mode for New technology based SMEs [4]. Korean government also has considered venture capital investment as one of the important financing instruments and established several public policies encouraging venture capital. However, there are few empirical studies that investigate the effects of venture capital investment on biotech SMEs in Korea. In this paper, we examine direct and indirect effects of the venture capital investment on innovative performance of biotech SMEs in Korea.

Venture capital investments are defined as equity-linked investments in young, privately held companies, where the investors are financial intermediaries [5]. Previous studies from developed countries have often highlighted the role of the relaxation of financial constraints, coaching, and networking in venture capital investments [4]. Venture capital investments facilitate the funded firm's efforts to obtain other necessary resources. They are particularly skilled at injecting expertise and sound business judgment into investee firms [6]. According to several empirical studies, venture capital investors often perform a key coaching function for the benefit of investee firms [4], [7]. They provide investee firms, which typically lack internal resources, with advising services in fields such as strategic planning, marketing, finance and budgeting, and human resource management [4]. However, the manner in which venture capital investments influence a firm's innovation performance is not as certain.

In this paper, we empirically analyzed the impact of venture capital investments on networks and innovation performance in Korean biotech SMEs. The main questions that motivated this study were: what is the role of venture capital investments on inter-firm collaboration and innovation performance? What mechanisms of venture capital investment are influencing innovation in developing countries?

The remainder of the paper is structured into three sections. In Section II, we introduce a theoretical framework and research hypotheses, which is followed by data and methods in Section III. Finally, we present main results and discussion.

II. Hypothesis

In this study, we used value-chain based innovation system approach to define a framework. A value-chain based innovation system (VIS) is the combination of a theoretical framework of "systems of innovation" and Porter's concept of a value chain [8]. Porter's concept of a value chain was based on "the process view of organizations, the idea of seeing a manufacturing or service organization as a system," comprising "subsystems each with inputs, transformation processes and outputs"; a product passes through all activities of the chain in order and gains some value at each activity [8]-[10]. In the VIS framework, firms are divided into upstream and downstream companies [1], [10].

The biotechnology industry can use VIS analysis because biotech industries are "comprised of a value chain of highly interrelated but distinguishable activities" including R&D, clinical trials, evaluation, manufacturing and sales [1], [10].

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When considering the main actors in each process, biotech SMEs are located at the hub of a network of upstream and downstream relationships as presented in Table I. Much of the previous studies on inter-firm collaboration implicitly locates biotech SMEs at the upstream pole of the established firms (for example, pharmaceutical or agricultural biotechnology) along industry value chains [10]-[12]. On the other hand, many biotech SMEs collaborate with universities or public research institutions in what are referred to as upstream partnerships [10], [13]-[16]. Therefore, biotech SMEs serve as “value- added intermediaries” between upstream partners (e.g. universities) and downstream partners (e.g. established enterprises), taking on “a dual role of knowledge transformation and commercialization” [1], [10]-[16].

TABLE I: MAIN ACTORS IN EACH VALUE-CHAIN IN BIOTECHNOLOGY INDUSTRY [10]

Value chains	Main actors
R&D (Basic)	Universities, Public Research institutes
R&D (Application)	Biotech SMEs, Large established firms
Clinical trials/evaluation	Research hospitals, Firms specializing in clinicals
Manufacturing	Large established firms
Marketing	Large established firms

Firms receiving venture capital are able to tap into their investors contacts, benefitting from a larger network of potential new customers (e.g. downstream partners), suppliers (e.g. upstream partners), and alliance partners [4]. Furthermore, previous studies showed positive associations between inter-firm collaborations and a firm’s innovation performance.

Therefore, we tested a series of hypotheses on the relationship between venture capital investment and a firm’s innovation performance, as determined by inter-firm collaborations, which can be classified into upstream partnerships and downstream partnerships.

Hypothesis 1: Venture capital financing is positively related to inter-firm collaborations.

Hypothesis 1-1: Venture capital financing is positively related to upstream partnerships.

Hypothesis 1-2: Venture capital financing is positively related to downstream partnerships.

Hypothesis 2: Inter-firm collaborations are positively associated with firms’ innovation performance.

Hypothesis 2-1: Firms’ upstream partnerships are positively associated with firms’ innovation performance.

Hypothesis 2-2: Firms’ downstream partnerships are positively associated with firms’ innovation performance.

Hypothesis 3: Venture capital financing is positively related to firms’ innovation performance.

III. DATA AND METHODS

A. Data

The primary source of the study data was the firm survey conducted in January and February of 2009 [1]. In the survey, we collected the 3-year data from 2005 through 2007 except for information about patent application that was collected from the Korea Intellectual Property Rights Information Service [1]. The sample frame for the survey comprised SMEs (small and medium-sized entrepreneurs) in the biotechnology industry that were listed with the Korea Bio Venture Association, published by the Korea Bio Venture Association, were selected for the survey [1]. The questionnaire comprised three parts: (1) information about receiving venture capital investment; (2) collaboration activities; (3) general information about the firm in 2005, 2006, and 2007 [1], [10]. A total of 152 responses were received which provided a response rate of 46.6 percent [1]. Missing data were handled by listwise deletion-omission of all records that contained a missing data point for any one variable-and this yielded 125 useable responses. Table II shows the general characteristics of the sample: mean age was 8.9 years, mean number of employees per firm was 24.5, and 83.2% of the firms were engaged in R&D.

TABLE II: GENERAL CHARACTERISTICS OF THE SAMPLE (N=125)

Characteristics	Mean ± SD (Number of firms, %)	
Age up to 2007	8.9±5.8	
Number of employees	24.5±30.5	
Firm origin		
Independent	110	(88.0)
Spin-off from university or public research institute	8	(6.4)
Industry spin-off/joint venture	7	(5.6)
Type of primary product		
Bio-food	40	(32.0)
Bio-pharmaceutical	33	(26.4)
Biochemical	23	(18.4)
Bio-environment	11	(8.8)
Other	18	(14.4)
Firm activity in value chain (multiple answers)		
R&D	104	(83.2)
Marketing/Sales	72	(57.6)
Production	67	(53.6)
Evaluation	16	(12.8)
Clinical trials	14	(11.2)

B. Definition of Variables

The definitions of the variables used in this study are presented in Table III. The innovation performance of firms was measured by the number of patent applications. We constructed an indicator variable that takes the value one when the firm received venture capital investments and used the total number of formal ties as the measure of inter-firm collaboration, further splitting it into two subcategories: upstream and downstream collaborations. We also controlled the effect of several characteristics of a firm (size, age, position in value chain, internal research and development, etc.). Firm size was controlled by using the log value of the number of employees [10], [17]. Age was calculated based on the foundation year and month of the firm [10]-[12], [16], [18]. Two indexes, POSIT_R and POSIT_D, have been constructed for addressing a firm's position in the value chain, taking the value one when the firm conducted only R&D for POSIT_R and taking the value one when the firm was involved in both R&D and downstream activity for POSIT_D [10]. The ratio of R&D spending to was used as measure of R&D intensity [10]. Stock of patent was calculated as the depreciated sum of applied patents.

TABLE III: DEFINITION OF THE VARIABLES AND ABBREVIATIONS

	Variable	Definition
Dependent variable		
PAT	Innovation performance	Total number of patent applications to Korean Intellectual Property Organization in each year
Independent variables		
VC	Venture capital investment	1 if receiving investment from VC
UP	Upstream collaboration	Total number of partnerships with universities and research institutions
DN	Downstream collaboration	Total number of partnerships with firms
Control variables		
SPAT	Stock of patent applications	Depreciated sum of applied patents up to (t-1)
AGE	Age	Number of years since founding
SIZE	Size	Log of the number of employees
POSIT_R	Position in value chain (1)	1 if the firm only performs R&D activities, 0 otherwise
POSIT_D	Position in value chain (2)	1 if the firm performs both R&D and downstream activities, 0 otherwise
RD	R&D spending	Ratio of R&D spending to sales

C. Analytical Methods

For estimating the multi-equation model, we used a seemingly unrelated regression (SUR), which was formulated by Zellner [10], [19]. SUR is a regression in which two or more dependent variables are predicted by sets of predictor variables. In SUR, the estimates are weighted by the covariance of the residuals from the individual regressions which results in SUR producing more efficient estimates than OLS [10], [20].

Suppose that the ith equation in a set of m equations is

$$y_i = X_i\beta_i + u_i \quad i = 1, 2, \ldots, m \tag{1}$$

where y_i is an vector of observations on the ith variable, X_i is an $n \times k_i$ matrix of observations on independent variables, β_i is a $k_i \times 1$ vector of coefficients, and u_i is an $n \times 1$ vector of disturbances.

The set of equations can be written as

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{bmatrix} = \begin{bmatrix} X_1 0 & \cdots & 0 \\ 0 \ X_2 & \cdots & 0 \\ \vdots \ \vdots & \ddots & \vdots \\ 0 \ \ 0 & \cdots & X_m \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_m \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_m \end{bmatrix} \tag{2}$$

By definition the variance-covariance matrix for u is

$$\Sigma = E(uu') = \begin{bmatrix} E(u_1u_1')E(u_1u_2')\cdots E(u_1u_m') \\ E(u_2u_1')E(u_2u_2')\cdots E(u_2u_m') \\ \vdots \quad \vdots \quad \ddots \quad \vdots \\ E(u_mu_1')E(u_mu_2')\cdots E(u_mu_m') \end{bmatrix} \tag{3}$$

By assumption,

$$E(u_iu_j') = \sigma_{ij}I \quad i, j = 1, 2, \ldots, m \tag{4}$$

when Substituting (4) in (3)

$$\Sigma = E(uu') = \begin{bmatrix} \sigma_{11}I & \sigma_{12}I \cdots \sigma_{1m}I \\ \sigma_{21}I & \sigma_{22}I \cdots \sigma_{2m}I \\ \vdots & \vdots \ \ddots \ \vdots \\ \sigma_{m1}I & \sigma_{m2}I \cdots \sigma_{mm}I \end{bmatrix} = \begin{bmatrix} \sigma_{11} & \sigma_{12} \cdots \sigma_{1m} \\ \sigma_{21} & \sigma_{22} \cdots \sigma_{2m} \\ \vdots & \vdots \ \ddots \vdots \\ \sigma_{m1} & \sigma_{m2} \cdots \sigma_{mm} \end{bmatrix} \otimes I = \Sigma_c \otimes I \tag{5}$$

where I is the identity matrix of size n equal to the number of cases in the analysis and the $\otimes$ is Kronecker multiplication: each element in is multiplied by I [10], [21].

The set of equations are estimated as a group. The GLS estimator is

$$b_{GLS} = (X'\Sigma^{-1}X)^{-1}X'\Sigma^{-1}y \tag{6}$$

where

$$\Sigma^{-1} = \Sigma_c^{-1} \otimes IE(uu') = \begin{bmatrix} \sigma^{11}I & \sigma^{12}I \cdots \sigma^{1m}I \\ \sigma^{21}I & \sigma^{22}I \cdots \sigma^{2m}I \\ \vdots & \vdots \ \ddots \ \vdots \\ \sigma^{m1}I & \sigma^{m2}I \cdots \sigma^{mm}I \end{bmatrix} \tag{7}$$

The variance-covariance matrix for the GLS estimator is

$$\mathrm{var}(b_{GLS}) = (X'\Sigma^{-1}X)^{-1} \tag{8}$$

We analyzed the 3-year panel data using a one way fixed time-effects SUR model.

IV. RESULTS AND DISCUSSION

Correlations between the variables are presented in Table IV and results of the SUR analysis are presented in Table V.

Inter-firm collaborations with upstream partners were positively correlated with a firm's innovation performance, supporting Hypothesis 2-1 (β=0.18, p<0.10). Biotech SMEs maintain broad and deep interaction with universities because these interactions increase a firm's stock of knowledge [16]. Zucker *et al.* investigated co-authorships in the biotechnology industry and argued that new biotechnology firms have a strong dependence on university science research [10], [15], [22], [23]. George *et al.* found that companies with university linkages had higher levels of innovative output [13]. Baum *et al.*'s study showed that biotech start-ups, which had upstream partnerships, generally exhibited stronger performance [24]. The results of our empirical study showed that relationship between venture capital investments and upstream partnerships was positive but statistically insignificant.

We found a strongly significant positive relationships between venture capital investments downstream partnerships, supporting Hypothesis 1-2 (β=0.29, p<0.001). Downstream activities such as production and marketing are scale intensive activities. While new biotech SMEs specialize in certain types of knowledge, products, and applications, downstream entities such as large established firms have expertise in the commercialization of new inventions that involve large-scale production, marketing and distribution, and regulatory processes [25]. Furthermore, Audretsch found that procuring complementary assets through market exchange is more efficient than acquiring them through internal transactions [26]. Since scale-intensive activities are likely to present more severe obstacles to SMEs, downstream partnerships maybe helpful in overcoming obstacles and entering markets [6]. Because venture capital investors benefit if the investee firm does well and their investment is realized, they maybe more focused on downstream partnerships than upstream partnerships.

TABLE IV: CORRELATIONS BETWEEN VARIABLES FROM THE POOLED 3-YEAR PANEL DATA (*N*=375)

	PAT(*t*+1)	AGE	SIZE	POSIT_R	POSIT_D	RD	SPAT	VC	UP
PAT(t+1)	1								
AGE	0.11 *	1							
SIZE	0.36 ***	0.54 ***	1						
POSIT_R	-0.01	-0.09	-0.18 ***	1					
POSIT_D	0.11 *	-0.07	0.23 ***	-0.68 ***	1				
RD	0.04	-0.12 *	-0.27 ***	0.16 **	-0.06	1			
SPAT	0.43 ***	0.08	0.26 ***	0.11 *	0.07	0.03	1		
VC	0.18 ***	0.03	0.21 ***	0.08	0.03	0.09	0.36 ***	1	
UP	0.24 ***	0.06	0.20 ***	0.05	0.12 *	0.10	0.21 ***	0.16 **	1
DN	0.24 ***	0.02	0.09	-0.03	0.14 **	0.05	0.18 ***	0.24 ***	0.22 ***

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.10$

TABLE V: COEFFICIENTS OF THE MODEL ESTIMATED IN THE SEEMINGLY UNRELATED REGRESSION

Explanatory variable		Dependent Variable			
		VC	UP	DN	PAT(t+1)
Independent variables	VC		0.16	0.29 ***	-0.36
	UP				0.18 +
	DN				0.61 **
Control variables	SPAT	0.03 ***	0.03 *	0.01 +	0.17 ***
	RD	0.08 *	0.23 +	0.03	0.45 *
	AGE	0.00	0.00	0.00	-0.03 +
	SIZE	0.18 ***	0.38 **	-0.01	1.66 ***
	POSIT_R	0.05	0.33 *	0.05	-0.12
	POSIT_D	0.01	0.32 **	0.15 *	-0.14
RMSE		0.28	0.79	0.45	1.59
R-sq		0.17	0.11	0.08	0.30
chi2		77.5 ***	48.4 ***	34.64 ***	162.9 ***

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.10$

Downstream partnerships were positively correlated with a firm's innovation performance, supporting Hypothesis 2-2 (β=0.61, p<0.01). When comparing the magnitude of coefficients, it can be found that the effects of downstream partnerships are larger than those of upstream partnerships. Previous studies showed that the complementary nature of collaborations between biotech SMEs and established companies encourages firm performance as well [10]. Rothaermel and Deeds found an inverted U-shaped relationship between the number of alliances and firms' performances [10], [12], and Baum et al. showed that biotechnology firms with downstream alliances generally exhibit strong initial performance [10], [24].

Results of this study showed no significant direct effect of venture capital investments on innovation performance.

Based on the results of the empirical study, we suggest that venture capital investments influence innovation performance by promoting downstream collaborations.

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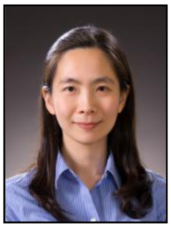

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