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Factors Affecting the Survival of SMEs: A Study of Biotechnology Firms in South Korea

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Academic Editor: Yongrok Choi
Received: 9 November 2016; Accepted: 9 January 2017; Published: 13 January 2017

Abstract: Past studies examining survival factors of biotechnology firms have focused on pioneer countries, such as the USA, the UK and Germany. However, as the biotechnology industry in Asia is reaching the take-off stage and showing a high growth rate, the research on survival factors in the context of Asian latecomers is needed. The present research investigates internal and external factors affecting the survival of SMEs (Small and Medium-sized Enterprises) in the biotechnology industry in South Korea. The Cox hazard model was employed to perform a robust estimation in survival analysis. The analysis of internal factors showed that the origin of a firm (i.e., having prior experience or spin-offs) and the business sub-sector (i.e., platform-based) affect the hazard rates of biotechnology firms. In terms of external factors, unlike strategic alliances, government R&D funding lowered hazard rates for the firm's survival. Additionally, considering that the reasons of firm exit can be divided into bankruptcy and M&A (Mergers and Acquisitions), the different effects of origins from other firms and strategic alliance for firm survival are confirmed. The results suggest that prior experience, platform-based and constant government R&D funding contribute to the sustainable development of SMEs in the biotechnology industry.

Keywords: firm survival; firm origin; platform-based firm; government R&D funding; strategic alliance; SMEs; biotechnology industry

1. Introduction

The development of new drugs to meet rapidly growing medical demand faces many challenges. Despite the continuous increase of R&D investment in the pharmaceutical industry, the number of new drugs being approved is stagnant, showing a decrease in R&D productivity caused by challenges faced in the development process of new drugs. In 2012, the global pharmaceutical market was worth 9895 billion dollars, showing an average annual growth of 6.3% from 2007 to 2012; it is expected to reach 1.1799 trillion dollars in 2016. The annual growth rate, however, which was 9% in 2003, slowed to a record low of 3.5% in 2012 [1]. Considering these challenges, the pharmaceutical industry has shifted its focus from synthetic chemical drugs to bio-drugs [2]. The proportion of bio-drug sales among the global top 100 drugs is expected to increase sharply from 34% in 2011 to 49% in 2018 [3].

The development process of biotechnology is technology-intensive [4], and there are more small entrepreneurial firms in the biotechnology industry than in other industries [5]. SMEs in biotechnology industry face many challenges ranging from basic R&D to commercialization [6]. In particular,

compared with pioneers in the biotechnology industry, such as the USA, the UK and Germany, Asian latecomers, such as South Korea, China and India, where the industrial ecosystem has not yet developed, face more difficult problems and need strategies to ensure their survival at the firm or national level [7,8]. It has been considered that a firm's survival is based on its performance of business activities [9], which is critical for economic growth [10]. In particular, given the high level of business risk in the late-blooming Asian biotechnology industry, survival may serve as a sufficient condition for outperforming the global competition and maintaining, and even increasing, national economic growth [11].

Previous studies have shown that firm size and age [12,13], business diversification [14], technology innovativeness, such as R&D intensity, patents and new products [15], and industrial growth potential measured as entry and exit rates [16] are important factors in firm survival. Scholars of the biotechnology industry have emphasized that they must recognize the constraints on resources and capabilities and should connect with external organizations to prevent firm failure [17–19]. However, few studies on firm survival take this integrated view of the biotechnology industry. This study contributes to such an integrated perspective by examining both the internal factors (the microscopic perspective) and the external factors (the mesoscopic perspective) affecting the survival of SMEs in the biotechnology industry.

Important internal factors in the survival of biotechnology firms include their founding type (i.e., independent firm or corporate venture) [17,20] and business sub-sector (i.e., therapeutic product area or platform area) [21,22] at the time of the firm's founding. Biotechnology firms should also make an effort to recognize their environmental conditions in order to prevent business risks caused by industrial transitions [23], to identify business opportunities [24] and to obtain complementary resources and capabilities to gain a competitive advantage [18,19]. In terms of external factors, biotechnology firms should engage in strategic cooperation with governments and other stakeholders, such as universities, hospitals, government-funded research institutes and other biotechnology and pharmaceutical firms [25,26].

Few studies have examined the survival of Asian biotechnology firms. Most biotechnology industry studies focus on pioneers in the USA, the UK and Germany. However, differences among industrial and national innovation systems may produce different survival rates and factors between pioneers and Asian latecomers of the biotechnology industry [27]. Therefore, studies in the Asian context are necessary. The present research used data from biotechnology firms in South Korea as one of the Asian latecomers of the biotechnology industry. Although the biotechnology market in South Korea was worth only KRW (1 US dollar = 1147.50 KRW (Korean won) as of 2 November 2016) 3.7 trillion as of 2011, with bio-pharmaceuticals accounting for the largest share (43.6%) at KRW 1.6 trillion, it has shown a high annual growth rate of 11.5% since 2009 [28]. Thus, this study looks forward to provide important implications for Asian countries, where the biotechnology industry is reaching the take-off stage, by identifying the factors that affect the survival of latecomers to this industry.

The remainder of this paper is organized into four sections. Section 2 provides the theoretical background and hypotheses, discussing the perspective of this study and the internal and external factors affecting the survival of biotechnology firms, from which hypotheses can be deduced. Section 3 describes the data, analysis model and variables, and Section 4 presents the analysis results. Section 5 discusses the implications, limitations and directions for future research.

2. Theoretical Background and Hypotheses

This study investigates internal factors inherited from the firm's founding, namely the characteristics of (1) origins from other firm and (2) platform-based firm, and external factors, such as firm's proactive behaviors obtaining their complementary assets and hedging their business risk, i.e., (1) government R&D funding and (2) strategic alliances. This study contributes to finding survival factors and discussing their implications from an integrated perspective and considers

internal and external factors for the survival of small enterprises in the context of the late-blooming Asian biotechnology industry in South Korea.

In this study, survival factors for biotechnology firms are described based on the resource-based view and strategic choice theory. We assume that these factors may have different values or costs as resources and capabilities and firms can proactively select the survival factors that suit their context. First, the resource-based view argues that the differences in firms' resources and capabilities determine their survival and growth [29], based on the assumption that a firm is a unique aggregate of tangible and intangible resources and capabilities. Using the benefits stemming from specific resources and capabilities, a firm achieves a short-term performance that is internalized as organizational capacity that cannot be easily transacted, at which point the firm can realize sustainable growth based on its long-term advantages [30].

Strategic choice theory emphasizes that firms actively make decisions against environmental change in order to grow and survive [31,32]. This theory originated in resistance to population ecology theory, which explored the principle of industrial evolutionary thinking [33]. In population ecology theory, the survival and exit of an organization are determined chiefly by environmental factors, and each organization and organizational group fights to secure resources and capabilities [34]. However, population ecology theory leans too heavily on environmentalism and, thus, underestimates the possibility of proactive responses and strategic choices by firms [35]. Strategic choice theory emphasizes that firm strategies should be recognized by a series of the exercise of decision makers' choices [36,37]. According to strategic choice theory, firms respond actively to their own situation and circumstances [38,39].

2.1. The Origin of a Firm

Heirman and Clarysse [40] highlighted that differences of firm's initial resources, such as human, technological and business capabilities and funds, influenced the direction of the firm's business strategies. Zahra [17] and Zucker and Darby [41] highlighted that founders from research organizations, such as universities, hospitals and government-funded research institutes, can gain competitive advantages in terms of knowledge. When a firm is spun-off from a high-tech university, the characteristics and capabilities of the entrepreneurial team are closely related to the direction of business development [42]. This is because biotechnology R&D is based on basic science, which can be learned through accumulated tacit knowledge [6]. Thus, the initial resources and capabilities inherited by founders from a research organization may play a key role in the survival of biotechnology firms [43]. However, founders from research organizations tend to be concerned about their research interests, instead of putting effort for their business to settle and succeed [44]. Although founders from research organizations have business opportunities that can commercialize their knowledge base, their different entrepreneurial propensities and managerial capabilities have led to inconsistent results for financial performance and survival [42,45].

On the other hand, some studies have shown consistent results regarding the advantages for the survival of entrepreneurial firms that either have founders with experience in other companies or are spin-offs from parent companies [46–48]. First, founders that have work experience in other companies generally establish independent ventures in the management unit, which provides them with superior management capabilities. Therefore, these firms can more actively respond to the risks posed by industrial characteristics and economic circumstances, as well as management risks [46]. Deeds and Hill [47] emphasized that founders with background knowledge or experience in the biotechnology industry could better manage relationships with employees and improve performance. Wennberg et al. [48] argued that, for firms' financial performance and survival, the commercial knowledge acquired from work experience in other companies is more important than the academic knowledge obtained through research experience at universities. This implies that managerial knowledge and the capabilities of the founder acquired through prior firm experience are important for the survival of biotechnology firms.

Additionally, corporate ventures spun-off from parent companies have a longer survival period than independent ventures [49]. Buenstorf [49] argued that the survival rate of corporate ventures may be better than that of other venture types. Zahra [17] and Zahra and George [20] showed the advantages of corporate ventures regarding resources and capabilities for R&D and product manufacturing in the biotechnology industry. In these cases, the resources and capabilities that corporate ventures can acquire from their parent companies, such as funding, human resources, technologies, manufacturing and marketing capabilities and reputation, can play an important role in their survival. Arregle et al. [50] also highlighted the positive effect of resource support from a parent company on new firms' growth and survival. In addition, LeBrasseur et al. [51] emphasized that the breadth of pre-startup activities was more important for business performance than owner manager's technological capabilities in new venture start-ups. All of this suggests that advantages in resources and capabilities, stemming from the parent company are important for the survival of biotechnology firm. In sum, when a biotechnology firm is either established by founders with work experience in other companies or spun-off from a parent company, the possibility of firm survival will be increased. Therefore, this study suggests the following hypothesis:

Hypothesis 1 (*H1*). *Biotechnology firms that are established by founders with work experience in other companies or spun-off from a parent company lower hazard rates for their survival.*

2.2. Platform-Based Firm

In general, biotechnology has the characteristics of scientific uncertainty, complexity with multiple disciplines and cumulativeness to learn from many failures [6,52]. In addition, biotechnology products are required to meet strict regulations because they target human beings, which can be an obstacle to firm survival [53]. These factors pose challenges in biotechnology R&D. Different types of biotechnology firms face different R&D challenges. Willemstein et al. [22] and Chiaroni et al. [54] argued that biotechnology firms can be divided into two categories: (1) therapeutic product-based firms, which provide intermediate materials and finished products related to biomedicine, companion diagnostic kits and reagents; and (2) platform-based firms, which provide either platform technology related to cell culturing, purification and analysis or support services, like cell banking.

Compared to therapeutic product-based firms, platform-based biotechnology firms have relatively higher advantages for their survival. The technological and financial risk of platform-based biotechnology firms is lower than that of therapeutic product-based firms [55]. The reasons are as follows. First, compared to therapeutic product-based biotechnology, platform-based biotechnology is likely to have lower R&D and business risk. In platform-based biotechnology, greater technological capabilities related to mechanical or electronic mechanisms are required and less technological risk is involved [6,54]. They also operate in a specialized area of the value chain. Thus, they can shift the burden on resources and capabilities from R&D to new products and reduce business risk [56]; Second, the business model of platform-based firms is directly related to revenues because they execute various projects in a specialized area of the value chain, whereas therapeutic product-based firms execute one or two projects with high business risk from basic R&D to the commercialization stage [22]. Together, platform-based firms are likely to survive with the relative advantages of resources and capabilities because of low business risk. Therefore, the following hypothesis is proposed:

Hypothesis 2 (*H2*). *Platform-based biotechnology firms lower hazard rates for their survival.*

2.3. Government R&D Funding

The biotechnology industry is considered to be an industry with high market failure due to the uncertainty of the development process from basic R&D to commercialization [57]. Guellec and La Potterie [58] argued that the government R&D funding for this industry should be encouraged by reducing imperfect appropriability and risk. Therefore, government R&D funding in the biotechnology

industry has been considered as an institutional countermeasure for preventing market failure [6]. However, previous studies found that government R&D funding is not granted at random [59–61]. They described that firms receiving government R&D funding are highly likely to have better financial stability based on the firms' size and age and better technological innovativeness than those who have not. It reflects that founders in biotechnology firms should proactively make efforts to receive government R&D funding as one of their strategic choices.

Most studies have shown that government R&D funding can increase technological innovation performance [62–64]. In Germany, Czarnitzki and Licht [62] found that a firm that had received government R&D funding had better patent performance than firms that had not. In Canada, Cantner and Kösters [63] confirmed that firms that received government R&D funding experienced better patent performance. Kang and Park [64] demonstrated that government R&D funding had a positive effect on patent performance of biotechnology firms in South Korea.

These results indicate that government R&D funding may underpin the survival of biotechnology firms to a certain extent, enhancing their technological innovation performance [15,65]. Christensen et al. [65] also demonstrated that firms' technology innovation enhanced the probability of their survival in the disk drive industry. Cefis and Marsili [15] argued that technological innovation performance could increase the possibility of firm survival and that its effect increased over time based on the Community Innovation Survey in the Netherlands. These findings imply that government R&D funding promotes technological innovation performance, which ultimately has a positive influence on firm survival. Therefore, this study suggests the following hypothesis:

Hypothesis 3 (*H3*). *Biotechnology firms with government R&D funding lower hazard rates for their survival.*

2.4. Strategic Alliance

A few studies explore open innovation, such as strategic alliance of SMEs, relative to high-technology multi-national firms [66]. Bigliardi and Galati [67] found that factors, such as insufficient knowledge, little experience of collaboration, lack of funds and the absence of organization, hinder the adoption of open innovation for SMEs. Freel and Robson [68] emphasized that informal intellectual property affects SMEs to absorb knowledge through open innovation.

Generally, biotechnology firms, which are mainly SMEs, play a role in commercializing the basic research results of research organizations like a university and transferring them to pharmaceutical companies [6,26]. This has helped biotechnology firms establish a variety of alliance networks to commercialize the basic research results of research organizations and carry out technology development, manufacturing, marketing and investment with other biotechnology firms and pharmaceutical companies [18]. Small-sized entrepreneurial firms in particular should strive to acquire complementary assets through cooperation with various external organizations as a strategic choice because they lack the resources and capabilities to hold themselves against competitors in the rapidly-changing industrial environment [69,70].

Previous studies have shown that a strategic alliance can increase the firm survival rate through the acquisition of complementary R&D and manufacturing and marketing assets [18,71–77]. Delmar and Shane [74] analyzed the survival factors of Swedish firms and found that the ability to overcome the weak point in a social relationship through the establishment of relationships with external stakeholders, i.e., strategic alliances, is an important factor for firm survival. Raz and Gloor [77] proved that building strategic alliances is critical for the survival of a firm in the Israeli software industry.

These results can also be applied to the biotechnology industry. Past studies have demonstrated that if biotechnology firms have sufficient alliance management capability or absorptive capacity, their technological innovation performance or financial performance can benefit from a strategic alliance [72,75]. In particular, Baum et al. [18] and Tsai and Erickson [76] emphasized that strategic alliances count in regard to the growth of a biotechnology firm in its initial stages. The possibility of survival is increased via performances created by strategic alliances among biotechnology firms.

Furthermore, through an analysis at the country level, Cooke [71] noted that the survival rate of biotechnology firms in the UK was lower than that of firms in the USA because the strategic alliances of the UK biotechnology firms were not active. Oliver [73] analyzed the strategic alliances of biotechnology firms in the USA and demonstrated that biotechnology firms with a lower number of strategic alliances showed a lower possibility of survival. Together, these results imply that strategic alliances can have a positive effect on the survival of biotechnology firms. Therefore, the following hypothesis is proposed:

Hypothesis 4 (*H4*). *Biotechnology firms with strategic alliances lower hazard rates for their survival.*

The research model is summarized in Figure 1.

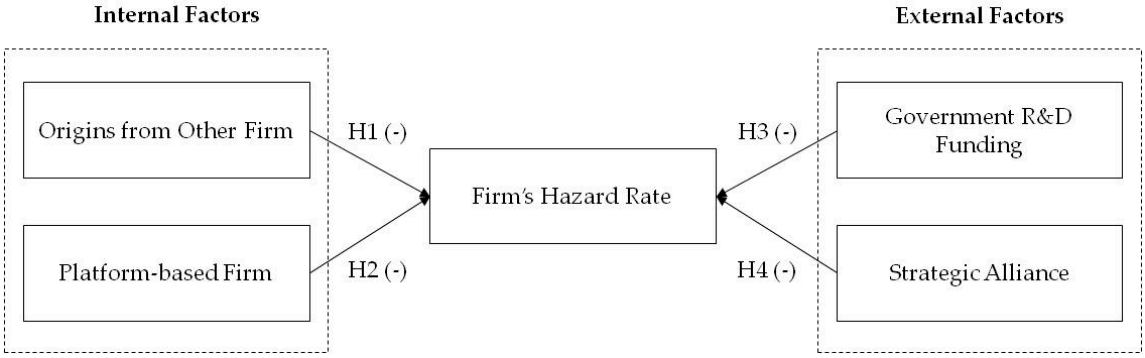

Figure 1. Research model.

3. Data and Method

3.1. Data

This study used the database (DB) of biotechnology firms collected by the Science and Technology Policy Institution (STEPI) of Korea. The STEPI DB of biotechnology ventures targeted South Korean biotechnology firms in operation from 1992 to 2012 and confirmed the existence of 1054 biotechnology firms in Korea. The basic information, including founder's career trajectory, the areas of business and financial information, such as R&D intensity, was obtained from the DB of Korean Enterprise Data (KED). The information on government R&D funding was obtained from the National Science and Technology Information Service (NTIS) DB, and the number of strategic alliances was collected from daily newsletters distributed by Korea Biotechnology Industry Organization (KoreaBIO) or the Biotech Policy Research Center (BPRC) of South Korea.

Due to the lack of data on strategic alliances, this study limited the period of analysis from 2005 to 2012. In addition, the STEPI DB of biotechnology firms includes all firms engaged in drug, diagnostic kits and reagents, agriculture, food, chemistry, environment, energy, supporting services and measurement and analysis equipment. Among the 756 therapeutic product- or platform-based firms in the Korean bio-medical industry, 618 firms were selected, excluding 134 firms that could harm the robustness of the analysis due to a high volume of missing values and 4 firms that conducted backdoor listing. In addition, the target data of this study contain a great deal of censored data. For this study, a total of 3824 data of 618 firms from 2005 to 2012, which include information of all firms from the founding year, were used.

The distribution of biotechnology firms for each business area is presented in Table 1. The business areas are divided into the therapeutic product area (i.e., bio-medicine, diagnostic kits and reagents) and the platform area (i.e., supporting services, measurement and analysis equipment). Based on a count of the most representative business areas, the therapeutic product area accounted for 63.60% of the total, while the platform area accounted for 36.40%. To be specific, the bio-medicine and supporting

service areas were represented at higher levels of 52.43% and 26.05%, respectively, while diagnostic kits and reagents and measurement and analysis equipment areas occupied 11.17% and 10.35% of the total, respectively.

Table 1. Distribution of biotechnology firms according to business area.

Business Area		The Number of Firms	Proportion (%)	The Number of Firms	Proportion (%)
Therapeutic Products	Bio-Medicine	324	52.43	393	63.60
	Diagnostic Kits and Reagents	69	11.17		
Platform	Supporting Services	161	26.05	225	36.40
	Measurement and Analysis Equipment	64	10.35		
Total		618	100	618	100

3.2. Method

The Cox proportional hazards model is mainly used for survival analysis [78]. Although this model is known as a robust estimation method in survival analysis, actual events surrounding exits, such as bankruptcy and M&A, should reach an appropriate size during the analysis period. Due to this problem, this study utilizes the Cox hazard model with stepwise time-varying covariates, as an extension of the Cox proportional hazards model, for survival analysis. In the Cox proportional hazards model with survival period (T) and elapsed time (t), an object dies when $t > T$. If the death probability of an object is $f(t)$, regarding a certain brief elapsed time (Δt), the cumulative mortality function is $F(t) = \Pr(T \leq t)$, and the survival probability of the object is $S(t) = 1 - F(t) = \Pr(T > t)$. If the number of initial objects is n_0, the number of objects that survived to this point is calculated by multiplying the number of initial objects by $S(t)$. Therefore, the number of objects that die during the period of Δt is $n_o f(t)$. In sum, the probability $h(t)$, which represents the number of objects that died among those that survived to point t, is a hazard function and given by Equation (1):

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t + \Delta t > T | T > t)}{\Delta t} = \frac{f(t)}{S(t)} \quad (1)$$

The Cox proportional hazards model is a non-parametric model, assuming that a hazard function for an individual presented according to its unique characteristics is proportional to a baseline hazard function, as described in Equation (2). In this equation, $h(t)$ is a hazard function for an individual with time (t), individual firm (j) and covariate (x_j), and $h_0(t)$ is a baseline hazard function at time (t), which represents the value of the hazard function where all of the values of covariates (x_j) equal 0. In this way, the Cox model can analyze whether the changes in these covariates bring about proportional changes in the hazard rate within the model. In this sense, the Cox model is called a proportional hazard model.

$$h_j(t) = h_0(t) \exp(\beta_0 + x_j \beta_x) \quad (2)$$

If the covariate (x_j) is not a variable of time, $h_j(t)$ has a value proportional to $h_0(t)$, where the Cox proportional hazards model can be applied. This study, however, applies the value of covariates that change according to time to acquire actual exit events. In addition, this study used Cox regression with competing risks to increase the reliability of the analysis results. Competing events occur competitively with interest events. A situation in which no other event occurs when one of the events occurs is called a competing risk situation. In a competing risk situation, failure to consider the occurrence of a competing event may hinder the identification of the apparent effect of the independent variable on the dependent variable, survival rate. This study divided the exit of a firm into exit by bankruptcy and exit by M&A, which is a competitive risk situation. Therefore, we used the competing risk model to correct errors caused by competing events [79]. In existing studies that explore the factors influencing firm survival, variables for all factors are generally assumed to be covariates. This study aims to

find the factors for survival in the biotechnology industry and thus uses (1) origins from other firm; (2) platform-based firm; (3) government R&D funding and (4) strategic alliances as independent variables and the firm size, age, R&D intensity, business diversification and industrial growth potential as control variables, which have been largely utilized in previous studies.

The firm's origin reveals the resources and capabilities of the founder or founding team [80]. The firm's origins in biotechnology firms are categorized as two types: (1) independent ventures established by founders from research organizations, such as universities, hospitals and government-funded research institutes, or from other firms, such as biotechnology or pharmaceutical companies; and (2) corporate ventures established in the form of affiliates by parent companies to generate new profits or reduce business risks [17,18,20]. In this regard, this study regards whether founders with career at other companies or affiliation of a parent company are a covariate that represents the characteristics of origins from other firms.

Biotechnology firms can be classified into two types: (1) therapeutic product-based firms that produce bio-medicine and diagnostic kits and reagents; and (2) platform-based firms that provide platform technology and support services [22,53]. In this study, whether or not a firm is platform-based is used as a covariate.

Previous studies on government R&D funding have considered two indicators: (1) whether a firm is receiving government R&D funding; and (2) the amount of government R&D funding [63,81]. Although both of these indicators have been used in previous studies, it can be assumed that the amount of funding actually received is more closely related to the survival of a firm. Therefore, this study uses the log-transformed ratio of the total amount of government R&D funding provided for each firm through government R&D support projects in a given year as a proxy of government R&D funding. In this case, a very small value of '0.00001' was used when these values were '0' to ensure these values would not be excluded from analysis as missing values.

The strategic alliances of biotechnology firms can be categorized into two categories based on their strategic alliance motivation: (1) upstream alliance (R&D alliances); and (2) downstream alliance (manufacturing and marketing alliance) [82–84]. To verify the effects of these types of strategic alliances, previous studies have analyzed both the outcome of having a strategic alliance or not and the number of strategic alliances [85,86]. In this study, the number of strategic alliances in the pertinent year is used as a proxy of alliance effects. This assumes that cooperation is more closely related to the survival of a firm based on the premise that larger strategic alliances lead to the availability of more resources and capabilities [18]. Additionally, we examined the effects of strategic alliance according to motivation because it may operate differently for firm survival [87].

Firm size, age, R&D intensity, business diversification and industrial growth are used as control variables. Firm size is represented by the number of employees, and firm age is calculated by subtracting the year of foundation from the pertinent year [10]. This study also used the log-transform of value calculated by dividing the R&D expenditure by the amount of revenues [88]. However, it takes a substantial amount of time for a biotechnology firm to generate revenues, and thus, there are multiple zero values. In this context, each '0' value was replaced with a very small value of '0.00001' to ensure that these values would not be excluded from analysis as missing values. In addition, business diversification is measured as the number of business areas in bio-medicine, diagnostic kits and reagents, supporting services and measurement and analysis equipment. A proxy for industry growth was calculated by dividing the difference between the number of entrants and the number of firms exited by the number of existing firms, in the pertinent year [16]. The variables and operational definitions are summarized in Table 2.

Studies have argued that private R&D intensity is enhanced by government R&D funding [63,89] or promoted by strategic alliances that increase firms' absorptive capacity and provide higher market value [90,91]. Thus, multicollinearity among the variables is checked by using the variance inflation factors (VIF) test. The highest VIF among the variables in all research models is 2.493, which indicates

a good model fit, considering that the cutoff rule-of-thumb is below 10 for multiple regression models [92].

Table 2. Variables and operational definition.

Variable	Operational Definition
FIRMORI	1 if firm established by founder with work experience at companies or spun out from a parent firm, 0 otherwise
PLATFORM	1 if a platform-based firm, 0 otherwise
lnGOV	Log-transformed ratio of total amount of R&D funding supported by the government
GOV	Total amount of R&D funding supported by the government
ALLI	Number of strategic alliances
RDALLY	Number of R&D alliances
MMALLY	Number of manufacturing and marketing alliances
SIZE	Number of employees
AGE	Number of years since founding
RDIN	Log-transformed ratio of R&D expenses to revenues
DIV	Number of business areas in which the firm is engaged
GROW	The value resulting from dividing the difference between the number of entering firms and exiting firms by the number of existing firms in a given year

Note: FIRMORI means firm origin; RDIN means R&D intensity; DIV means business diversification.

4. Results and Discussion

Figure 2 illustrates the distribution of biotechnology firms in South Korea, describing the number of firms in terms of entry, exit by bankruptcy, exit by M&A and survival. In Korea, approximately 30 firms were established from 2005 to 2007, with the number of new firms peaking in 2008 and 2009 at 47 and 39, respectively. Since 2008, however, the number of new firms established has decreased to a record of 30 in 2010, 11 in 2011 and 12 in 2012. Firm exits were more frequently caused by bankruptcy than M&A, with the exception of 2007 and 2010. During the analysis period, the number of firms exiting due to bankruptcy was 53 (62%), while 33 firms (38%) exited due to M&A. This result shows a stark difference from the biotechnology industry in Canada, where from 1996 to 2010, 36% of exiting firms were bankrupt, and 64% had undergone M&A [93]. This clearly demonstrates the differences between the biotechnology industry in South Korea in which M&As are not actively conducted and the advanced biotechnology industry in Canada.

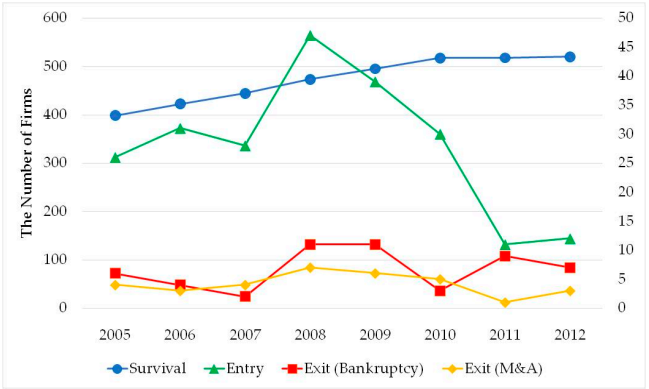

Figure 2. Distribution of Biotechnology Firms in South Korea. Note: the left axis is for entry, exit (bankruptcy) and exit (M&A); the right axis is for survival; the unit is the number of firms.

The basic statistics and correlation coefficients of the variables included in the analysis model are presented in Table 3. The results of analyzing the Cox hazard model with stepwise time varying covariates and the competing risks model are presented in Tables 4–6.

Table 3. Basic statistics and correlations.

Variable	Mean	Std. dev.	FIRMORI	PLATFORM	lnGOV	GOV	ALLI	RDALLY	MMALLY	SIZE	AGE	RDIN	DIV	GROW
FIRMORI	0.4268	0.4947	1											
PLATFORM	0.4345	0.4957	−0.0545 ***	1										
lnGOV	−5.3366	8.1560	0.0814 ***	−0.0155	1									
GOV	148.1536	398.6472	0.0141	0.0021	0.5436 ***	1								
ALLI	0.1456	0.6357	0.0038	−0.0019	0.1302 ***	0.2671 ***	1							
RDALLY	0.0594	0.3272	−0.0045	0.0311 *	0.0936 ***	0.1876 ***	0.8501 ***	1						
MMALLY	0.0861	0.3969	0.0098	−0.0287 †	0.1313 ***	0.2731 ***	0.9008 ***	0.5371 ***	1					
SIZE	37.6967	58.8286	0.1385 ***	−0.0141	0.0710 ***	0.1450 ***	0.1852 ***	0.1614 ***	0.1636 ***	1				
AGE	8.5180	5.4100	−0.0254 †	0.0153	−0.0166	0.0703 ***	0.1923 ***	0.2028 ***	0.1408 ***	0.3897 ***	1			
RDIN	−5.8467	5.3461	0.1237 ***	0.0156	0.3770 ***	0.1770 ***	0.0699 ***	0.0519 ***	0.0691 ***	0.0259	−0.0408 **	1		
DIV	1.3953	0.6429	0.0533 ***	0.0647 ***	0.1554 ***	0.0562 ***	0.1841 ***	0.0920 ***	0.0588 ***	0.0306 †	0.1006 ***	0.1673 ***	1	
GROW	0.0319	0.0221	−0.0224	−0.0103	0.0055	0.040 **	−0.038	0.0108	−0.0027	0.0320 *	−0.2542 ***	0.1094 ***	0.0199	1

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$.

Table 4. Analysis results of the Cox hazard model for Models 1, 2, 3, 4 and 5.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5	
	Estimate	Error	Estimate	Error	Estimate	Error	Estimate	Error	Estimate	Error
FIRMORI			−0.4297	0.1245 ***	−0.4457	0.1248 ***	−0.4356	0.1246 ***	−0.4228	0.1245 ***
PLATFORM			−0.8095	0.1240 ***	−0.7953	0.1240 ***	−0.8202	0.1239 ***	−0.8067	0.1241 ***
lnGOV			−0.0598	0.0101 ***			−0.0581	0.0100 ***	−0.0604	0.0101 ***
GOV					−0.0010	0.0003 ***				
ALLI			0.2452	0.0802 **	0.2694	0.0852 **				
RDALLY							0.3725	0.1736 *		
MMALLY									0.3594	0.1115 **
SIZE	−0.0097	0.0022 ***	−0.0080	0.0019 ***	−0.0082	0.0019 ***	−0.0078	0.0019 ***	−0.0081	0.0019 ***
AGE	−0.1476	0.0210 ***	−0.1680	0.0230 ***	−0.1583	0.0227 ***	−0.1677	0.0230 ***	−0.1682	0.0231 ***
RDIN	−0.1975	0.0152 ***	−0.1714	0.0155 ***	−0.1851	0.0154 ***	−0.1713	0.0155 ***	−0.1712	0.0155 ***
DIV	−0.4125	0.1099 ***	−0.3117	0.1128 **	−0.3067	0.1128 **	−0.3048	0.1125 **	−0.3087	0.1125 **
GROW	−2.1881	2.6154	−4.0944	2.6776	−3.8129	2.6700	−4.2209	2.6778	−3.9764	2.6776

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Model 1 is the basic model; Model 2 and Model 3 are the full model; Model 4 is the full model for R&D alliance; Model 5 is the full model for manufacturing and marketing alliance.

Model 1 in Table 4 is a basic model that conducted an analysis over control variables only, while Model 2 is a full model that considered both independent and control variables. Examining the control variables in Model 2, firm size ($p < 0.001$), age ($p < 0.001$), R&D intensity ($p < 0.001$) and business diversification ($p < 0.01$) all had a negative impact on the exit of biotechnology firms. This means that a larger and older firm has a higher possibility of survival. These results support previous studies that argued that firm size and age are important factors for firm survival [13,94]. In addition, R&D intensity also positively affects firm survival, showing the industrial property of technology intensiveness [88]. Moreover, a higher level of business diversification in a firm leads to a lower exit hazard. These results support a number of previous studies that argued that a firm engaged in multiple, varied business areas has a higher chance of survival by reducing business risks (e.g., Klepper and Simons [95]). On the other hand, the results contradict a handful of studies that concluded that a firm engaging in a single business area is more likely to survive [96]. However, the industry growth rate did not indicate a significant relationship with the hazard rate of firm exit.

Table 5. Analysis results of the Cox hazard model with competing risk for bankruptcy.

Variable	Model 6		Model 7		Model 8		Model 9	
	Estimate	Error	Estimate	Error	Estimate	Error	Estimate	Error
FIRMORI			−0.9348	0.1969 ***	−0.9192	0.1966 ***	−0.9385	0.1969 ***
PLATFORM			−0.3819	0.1407 **	−0.3696	0.1406 ***	−0.3925	0.1406 ***
lnGOV			−0.1114	0.0203 ***	−0.1117	0.0203 ***	−0.1114	0.0204 ***
ALLI			−0.7122	0.3455 *				
RDALLY					−0.6102	0.2850 *		
MMALLY							−2.0584	0.9731 *
SIZE	−0.0173	0.0035 ***	−0.0125	0.0033 ***	−0.0129	0.0033 ***	−0.0124	0.0032 ***
AGE	−0.0640	0.0243 ***	−0.0902	0.0264 ***	−0.0903	0.0264 ***	−0.0897	0.0263 ***
RDIN	−0.5965	0.0921 ***	−0.6009	0.1054 ***	−0.6031	0.1067 ***	−0.6000	0.1051 ***
DIV	−0.2418	0.1334 *	0.0004	0.1365	−0.0197	0.1372	0.0032	0.1363
GROW	0.2263	3.2648	−2.2383	3.3715	−2.1526	3.3694	−2.2562	3.3744

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Model 6 is the basic model; Model 7 is the full model; Model 8 is the full model for R&D alliance; Model 9 is the full model for manufacturing and marketing alliance.

Table 6. Analysis results of the Cox hazard model with competing risk for M&A.

Variable	Model 10		Model 11		Model 12		Model 13	
	Estimate	Error	Estimate	Error	Estimate	Error	Estimate	Error
FIRMORI			−0.4867	0.2194 *	−0.5171	0.2186 **	−0.4817	0.2193 *
PLATFORM			−2.0672	0.3312 ***	−2.0965	0.3309 ***	−2.0637	0.3312 ***
lnGOV			−0.0303	0.0129 *	−0.0254	0.0126 *	−0.0308	0.0130 ***
ALLI			0.3590	0.0797 ***				
RDALLY					0.6283	0.1834 ***		
MMALLY							0.4815	0.1066 ***
SIZE	−0.0043	0.0021 *	−0.0045	0.0022 *	−0.0043	0.0022 *	−0.0047	0.0022 *
AGE	−0.4061	0.0548 ***	−0.4348	0.0556 ***	−0.4394	0.0554 ***	−0.4322	0.0560 ***
RDIN	−0.0613	0.0183 ***	−0.0485	0.0188 ***	−0.0481	0.0189 ***	−0.0467	0.0188 **
DIV	−0.6278	0.1890 ***	−0.5308	0.1923 ***	−0.5312	0.1912 ***	−0.5242	0.1917 ***
GROW	−2.9882	4.4336	−5.1522	4.5313	−5.6622	4.5277	−4.8077	4.5430

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Model 10 is the basic model; Model 11 is the full model; Model 12 is the full model for R&D alliance; Model 13 is the full model for manufacturing and marketing alliance.

Origins from other firm had a positive effect on the survival of a biotechnology firm, supporting H1. In Model 2, the characteristics of a firm origin, specifically having founders with work experience at other companies or being spun-off from parent companies, had a negative relationship with the hazard rate ($p < 0.001$). This implies that founders' commercial knowledge or parent companies' resources and capabilities increase the survival probability of biotechnology firms. These results

support findings from previous studies (e.g., Wennberg et al. [47], Buenstorf [48]) that argued that the commercial knowledge of founders and the effect of parent companies are important for survival of firms.

The characteristics of platform-based firms also had a positive effect on firm survival, supporting H2. In Model 2, platform-based firms had a negative relationship with the hazard rate ($p < 0.001$). This means that platform-based biotechnology firms have survival advantages over therapeutic product-based firms. Casper and Kettler [21] found that the biotechnology industry in Germany could overtake that of the UK, stating that "Germany has a higher distribution of platform based firms than therapeutic product based firms". Casper and Kettler [21] emphasized that latecomers to the biotechnology industry could experience rapid growth by intensively nurturing the platform area, as those firms have a higher chance of survival, which is also supported by the present study.

Government R&D funding also had a positive effect on firm survival, supporting H3. In Model 2, government R&D funding for a biotechnology firm had a negative relationship with its hazard rate ($p < 0.001$), implying that government R&D funding is crucial to the survival of biotechnology firms. This result supports the findings of Lyles et al. [97], which emphasized the impact of government support on firm survival. In addition, the positive effect of government R&D funding on firm survival also can be explained by the fact that government R&D funding positively contributes to firms' competitive technological innovation performance, supporting the finding of Cefis and Marsili [15]. Biotechnology firms should make much effort to survive because government R&D support is not provided randomly. As the scale of the government funding has relatively high values comparing to other independent variables or control variables, we used a logged variable in order to normalize the distribution. However, to conduct a robustness check, we created Model 3 and analyzed it using only the total amount of R&D funding supported by the government. The results confirmed that the estimates and significance are similar to the Model 2 with a logged variable.

Strategic alliances had a negative impact on firm survival (H4 is not supported). In Model 2, biotechnology firms' strategic alliances had a positive relationship with firms' hazard rate ($p < 0.01$) indicating that strategic alliances are an important factor in firm exit. This result contradicts previous findings that show that strategic alliances improve the chance of firm survival by providing advantages in terms of managing outside competition or institutional challenges by complementing the resources and capabilities of a biotechnology firm (e.g., Baum et al. [18]). In Model 4 and Model 5, we further investigated the effect of strategic alliance according to motivation, which could distinguish R&D alliances from manufacturing and marketing alliances. However, both R&D and manufacturing and marketing alliances were shown to have a negative relationship with a firm's hazard rate ($p < 0.05$ and $p < 0.01$, respectively), implying that both types of alliance positively influence a biotechnology firm's exit, regardless of different motivation in strategic alliance. This finding implies that both R&D and manufacturing and marketing alliances promote firm exit.

This study analyzed closely the effect of two exit types of bankruptcy and M&A through Cox regression with competing risk. In particular, as shown in Table 4, Models 3, 4 and 5, the reason why strategic alliances have a negative impact on firm survival unlike previous studies is examined as follows. Model 7 in Table 5 and Model 11 in Table 6, which are full models, present the analysis results of the competing risk model on firm survival according to the reason of firm exit, bankruptcy and M&A, respectively. In the case of firms that exited after bankruptcy, origins from other firms, platform-based firms, government R&D funding, firm size and age and R&D intensity had a negative impact on firms' hazard ratios ($p < 0.001$, $p < 0.01$, $p < 0.001$, $p < 0.001$, $p < 0.001$ and $p < 0.001$, respectively). Strategic alliances in the competing risk model, however, also had a negative effect on firm hazard ratio, contrary to when both bankruptcy and M&A were considered as reasons of firm exit in the Cox regression model ($p < 0.1$). The results were the same in the case of both R&D alliance and manufacturing and marketing alliance in Models 8 and 9 of Table 5. In the case of firms that exited due to M&A, origins from other firms, platform-based firm, government R&D funding, firm size and age, R&D intensity and business diversification also had a negative effect on firms' hazard ratios ($p < 0.05$,

$p < 0.001$, $p < 0.05$, $p < 0.05$, $p < 0.001$, $p < 0.001$ and $p < 0.001$, respectively). When a biotechnology firm was forced to exit due to M&A, however, strategic alliances had a positive effect on its hazard ratio ($p < 0.001$). The results were the same in the case of both R&D alliance and manufacturing and marketing alliance in Models 12 and 13 of Table 6. This result of the competing risk model implies that strategic alliances help to decrease the hazard of bankruptcy and activate M&A. In particular, M&A, which serves as an important exit strategy for biotechnology firms, along with IPOs (initial public offerings) [98], entails relatively larger opportunity costs and risks than strategic alliances [99]. Therefore, it seems that the acquirer may intend to identify the target through a strategic alliance at first, with relatively low opportunity costs and risks [100].

The analysis results of the Cox regression with competing risk are summarized as follows. First, the effects of origins from other firm, platform-based firms and government R&D funding on firm survival showed similar results, although the results of analysis of the Cox hazard model and the competing risk model showed the slightest difference in values and significances; Second, additional analysis through the competing risk model revealed that strategic alliance helps to accelerate M&A and decrease bankruptcy; Lastly, this study also demonstrates that both R&D alliance and manufacturing and marketing alliance give negative effects on bankruptcy (Models 8 and 9 in Table 5) and positive effects on M&A (Models 12 and 13 in Table 6).

5. Conclusions

The present research contributes to identifying entry, exit and survival situations and to finding internal and external factors for survival of SMEs in the biotechnology industry, in South Korea. This study showed that firm exit due to bankruptcy is more active than exit due to M&A. This is different from the biotechnology industries of advanced countries, such as Canada, where firm exit due to M&A is more active than exit due to bankruptcy [93]. This study employed the Cox hazard model with stepwise time-varying covariates and demonstrated that origins from other firms, platform-based firm and government R&D funding all have a positive impact on the survival of biotechnology firms. Further, the origin from other firms and strategic alliances help to prevent bankruptcy and activate M&A.

The present research provides five implications. First, the industrial structure of a virtuous cycle should be formed for M&A in the South Korean biotechnology industry. Bankruptcy is generally more active than M&A in the exit period of this study, indicating that the South Korean biotechnology industry is less mature than its counterparts in advanced countries, such as the USA and Canada. After SMEs with promising technologies and knowledge accept an investment, the investors should withdraw them through IPOs and M&A. Countries with advanced biotechnology industries already enjoy such a virtuous cycle [6]. However, in the South Korean biotechnology industry, an Asian latecomer, firms must make an effort to activate M&A as an exit strategy by acquiring and developing their promising technologies and products and ultimately enhancing their firm value.

Second, the characteristics of origins from other firms provide an opportunity to develop the biotechnology industry in South Korea. They offer the competitive advantage of managerial excellence by preventing bankruptcies and activating M&A in biotechnology firms. There are many more firms that are founded by entrepreneurs with a career at other firms than by founders from research organizations [101]. This implies that founding firms from research organizations may be more difficult in South Korea than in advanced countries, such as the USA, due to differences in national institutional frameworks [21]. However, this study gives hope to Asian latecomers, such as South Korea and Taiwan, where fewer biotechnology firms originate in research organizations [102]. South Korea also has many well-known chaebol conglomerates [103]. The results of this study indicate the possibility of a "South Korean chaebol-dominated model" for the biotechnology industry. Resources and capabilities from parent companies provide small enterprises with competitive advantages for spin-offs.

Third, platform-based firms provide another opportunity to develop South Korean biotechnology industry. The ICT (information and communication technology) industry in South Korea and Taiwan has

traditionally played important roles in national economic growth and global competitiveness [102,104]. This study argues that platform-based firms with biotechnology-fused ICT may present another alternative for growth in the biotechnology industry of Asian latecomers with advanced ICT. In addition, the platform-based business model proved to be attractive for Asian latecomers, as it would allow biotechnology firms to concentrate on specialized areas without facing high risk while pursuing basic R&D through to commercialization.

Fourth, constant R&D support from the government is required for the development of the biotechnology industry in South Korea. Casper [8] emphasized that the remarkable growth of the South Korean biotechnology industry is due to intensive government support. Government R&D funding plays a key role in the growth and survival of SMEs, because South Korea has a bank-oriented financial system [103] and an immature venture capital financial system [8]. Thus, government R&D funding is a solution for the deficiency in private capital, such as venture capital in government-led Asian latecomers, such as South Korea, China and India, relative to advanced countries, like the USA [105,106]. Paradoxically, this also means that Asian latecomers must grow their private investment.

Fifth, strategic alliances must become more active in order to develop the biotechnology industry in South Korea. Asian latecomers to the biotechnology industry should form an industrial ecosystem to provide firms with complementary assets by encouraging strategic alliances among firms. Previous studies, such as Baum et al. [18] and Pisano [6], have argued for the significance of strategic alliances in bridging "islands", referring to biotechnology firms with unique core capabilities in countries with advanced biotechnology industries, such as the USA and Canada. Furthermore, the present research demonstrated that strategic alliances are important for both acquiring complementary assets to prevent bankruptcy and providing opportunities for M&A. The results indicate that strategic alliances in the biotechnology industry need to be active to prevent bankruptcies and revitalize M&A in Asian latecomers.

The limitations and the directions of future research are suggested as follows. First, the number of employees and business areas were treated as a constant, as of 2012, due to the lack of data. The change in the number of employees and business areas may be insignificant because South Korean firms are young on average, but these values can change according to the growth (or decline) or strategy of a firm. Future research can improve the present study by using a complete dataset; Second, the effect of private investments, such as venture capital, has not been considered for the survival of biotechnology firms. Pisano [6] explained the importance of venture capital for the USA biotechnology industry. However, in South Korea, the investment of venture capital is weaker than public (i.e., government) investment [8]. Regardless, considering the effect of private investment could provide comparative implications in future research.

Author Contributions: All authors worked collectively and significantly contributed to this paper. Kwangsoo Shin and Gunno Park designed the research and implemented the statistical analysis. Jae Young Choi and Minkyung Choy contributed to writing and provided a thorough literature review. All of the co-authors discussed the implications and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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