Effects of Organisation's Dynamic Capabilities on the Duration of Patent Commercialisation: The Case of Taiwan Biotechnological Industry

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Abstract--**In recent years, the commercialisation of technology has attracted considerable attention. The technology development process, from invention to commercialisation, contains numerous uncertainties and factors that influence the duration of patent commercialisation, such as appropriability, lead time, science linkage, and number of patent citations. However, most studies have neglected the relationship between organisational capabilities and the duration of commercialisation.**

This study used dynamic capabilities to construct a research framework for the factors that influence the commercialisation of biotechnological patents based on the primary theoretic basis of organisational capabilities. Following a literature review, this study proposed hypotheses regarding the influence that four major capabilities of an organization's dynamic capabilities have on the commercialisation of biotechnological patents. Data were collected using questionnaires distributed to companies in the biotechnology industry. Regarding the 119 questionnaires distributed, 28 of the collected questionnaires were valid. The validity and reliability of these questionnaires were analysed using SPSS 17.0. Subsequently, a survival analysis was conducted to verify the hypotheses proposed in this study. The results were used to verify whether the various dynamic capabilities, such as sensing, learning, and integration, as well as whether the possession of complementary assets, significantly influenced the feasibility of commercialising a specific patent. In addition, we examined whether company locations (within science parks or not) significantly influenced the feasibility of commercialising a specific patent.

I. INTRODUCTION

Innovation is considered crucial for enterprises to enhance competitiveness in an ever-changing environment [38]. Because of commercialisation, managers and scholars now regard the need to materialise innovation when enterprises plan innovative activities to be an important managerial topic [3; 37]. Typically, organisations protect their technologies and monopolise profits produced by their inventions through the application of patents. However, the process from invention to commercialisation involves significant expenditure (money and time) and uncertainties because a substantial amount of maintenance fees are incurred during the holding period, and not all patents can be successfully reduced to practice [3; 37]. A company's market competitiveness can be elevated and profits earned when technologies are commercialised as early as possible.

The process from invention to commercialisation contains numerous uncertainties. Several researchers have attempted to identify the complex factors that influence the duration of this process. Most studies regarding the factors that influence the duration of commercialisation have focused on the characteristics of the technologies or the patents that protect the technologies, such as appropriability (i.e., strength, scope, and trade secret), lead time, term of patent, science linkage, and number of patent citations. These characteristics have been employed to analyse the factors that influence the duration of commercialisation [12; 26; 34]. However, relevant studies have neglected to address the influence that organisational capabilities have on the duration of commercialisation. Specifically, occasional research on organisational capabilities and commercialisation has only analysed whether organisational capabilities facilitate the successful commercialisation of technology [7; 13; 24; 31; 38; 39]. Therefore, this study investigated the influence that organisational capabilities have on the duration of patent commercialisation.

Among the studies regarding the use of organisational capabilities to obtain profits from innovation through commercialisation, the research on dynamic capabilities conducted byTeece, Pisano and Shuen [39] and Teece [38] provided a comparatively more complete theoretical framework. Dynamic capabilities refer to the capabilities required for an organisation to be competitively advantageous in an uncertain environment [39]. These capabilities emphasise that organisations facing an ever-changing market should rapidly and flexibly implement product innovation, effective learning, and the integration and reconfiguration of internal and external resources to create competitive advantages [38; 39]. Nonetheless, empirical studies of organisation performance using dynamic capabilities as the theoretical framework are scarce, and most related studies have assessed performance based on organisational profits [23; 42; 43].

However, for organisations that allocate more resources to research and development (R&D), performance should not be assessed by turnover. The organisation's turnover may show deficits because the investment costs from initial invention to commercialisation are typically higher than the income earned. From the perspective of innovation, once a product enters the commercialization phase, this process is deemed successful, that is, the organisation's innovative performance is enhanced; therefore, a shorter process from invention to commercialisation facilitates an increase in innovative performance because innovation speed is considered a type of performance [5; 7; 23]. In addition, empirical research re-

garding the information technology industry has confirmed that dynamic capabilities influence innovation speed [23; 42]. This indicates that the timing of technology commercialisation decisions may be influenced by an organisation's dynamic capabilities. Therefore, this study used dynamic capabilities as the theoretical framework to verify the influences that these capabilities have on patent commercialisation.

In Taiwan, the biotechnology industry began attracting significant attention following the government's promotion of the *Two Trillion, Twin Star* (T3S) plan in 2002. In addition, the *Regulations for Promoting the Commercialization of Biotechnology* announced by the Ministry of Economic Affairs in 2005 and the implementation of *the Development of Biotech and New Pharmaceuticals Act* in 2007 have encouraged an increasing number of companies to pursue biotechnological innovation. A survey conducted by the Taiwan Institute of Economic Research in 2008 showed that although Taiwanese firms in the biotechnology industry have R&D budgets that account for up to 81% of their turnover; however, their major profits did not result from commercialised products of patented technologies. Therefore, this study contends that the adoption of policies promoted by the government does not guarantee profits for organisations through technological innovation activities. The relationship between organisational capabilities and innovative performance should be further examined. Thus, this study also investigated how organisations accurately and rapidly commercialise biotechnological patents.

By identifying the dynamic capabilities present in organizations, this study endeavoured to investigate the influence that these capabilities have on patented technologies. By conducting statistical analyses, we identified the capabilities that influence an organisation's innovative performance, that is, whether such capabilities were specifically related to the duration of technology commercialisation. Furthermore, we provided suitable recommendations for organisations formulating strategies to develop dynamic capabilities to enhance their innovative competitive advantage.

II. BACKGROUND THEORIES AND HYPOTHESES

A. Definition of Technology commercialisation

For an organisation, technology commercialisation refers to the process of profiting from technology development by manufacturing or selling products related to a certain technology. In recent years, several scholars have provided more comprehensive definitions of technology commercialisation. They proposed that technology commercialisation includes the selling, transferring, or leasing of technology ownership to an existing company; the establishment of a new company with technologies; and the implementation of technologies in products and manufacturing processes [20; 34; 36; 37]. Thus, technology commercialisation is defined as the sequential development, design, creation, completion, and practice of technology or the process in which technology transforms into a priced product [18; 20].

B. Related studies on the influences of patent commercialisation

All organisations typically endeavour to protect their technologies through the mechanism of intellectual property rights (IPRs). However, IPRs holdings produce immense maintenance fees. Organisations that successfully commercialize their technologies are able to obtain profits to cover these maintenance fees or produce additional tangible and intangible benefits for the organization [1; 37]. For example, Kelm et al. [19] investigated how research and innovation affected a company's stock value. Selecting 793 U.S. listed companies for empirical research, their results showed that when innovations were announced, the average stock value of the companies increased 0.88%, and when new products were launched, the value increased 1.02%. Therefore, technology commercialisation not only produces profit for the company, but also elevates company value. In addition, Arora and Ceccagnoli [3] and Motohashi [25] contended that the licencing of technologies obtains not only royalties but also complementary assets and key technologies essential for a company [37]. The capability of technology commercialisation, which should be developed by an organisation, represents an organisation's market competitiveness [27].

C. Dynamic capabilities

Successful commercialisation should include technology push and market pull strategies, integrating them with company resources, finances, and managers' methods for arranging technologies [9; 10]. Nevens [27] further asserted that commercialisation covers various stages of product design, development, manufacturing preparation, marketing, and subsequent improvement, and these stages should be considered a succession of procedures that equip the company with superior commercialisation capabilities. Procedures such as product design and marketing are closely related. The results of product design determine the difficulty of development, which influences the resources required for product manufacturing and marketing. In summary, market- and technology-orientated factors should be considered to ensure a continuous process. Subsequently, we investigated which capabilities companies require to commercialise technologies without difficulty.

This study contends that dynamic capabilities are the sensing capabilities required for a company to assess the market and seize opportunities in a rapidly changing environment. In addition, a company's situation and position in a competitive market can be reflected in their commercialization capabilities through the integration, learning, and reconfiguration of internal and external resources and knowledge [14; 21; 30; 35; 39].

1) Sensing capability. Sensing is an important capability for a market-oriented organisation. Related market information is thoroughly investigated based on potential demands and analysis of competitor behavior. This enables the organization to predict opportunities and respond to threats, and can

even filter, rectify, and more accurately predict market responses to organizational strategies. In addition, the development of future technologies can be more easily forecasted if an organization frequently explores new knowledge [8; 11; 38]. An organization's uncertainty regarding its resources and management, and unfamiliarity with the market hinders the maintenance of competitive advantages.

Compared with other topics, few studies have focused on the continuation of sensing. The studies examining this capability primarily discussed the appropriate definition instead of conducting quantified verification. Teece [38] asserted that enterprise performance results from the ability to sense market opportunities and technologies. Sensing includes external technological development, the assessment of customer needs, the innovation activities of suppliers and complementors, internal R&D, and the selection of new technologies. For second movers, market sensing has greater importance. When pursuing mainstream technologies, if second movers cannot identify the necessary technologies, profitable opportunities are missed [22]. Research regarding the performance of organisational innovation indicates that market changes generate opportunities for the technologies of an organization. Subsequently, organizations that are able to realize this concept can reduce the duration preliminary research regarding the anticipated market value and feasibility of product realisation and manufacturing, thereby enabling the organisation to more rapidly reduce the patent commercialisation duration. Therefore, we argue that sensing capacity positively influences technology commercialisation decisions. In other words, sensing capability positively influences the feasibility of commercialising a technology.

H1: A higher organisational sensing capability increases the feasibility of technology commercialisation.

2) Learning capability. Learning refers to the organisation's ability to understand external knowledge and establish useful internal knowledge. In addition, this capability assists an organisation in assessing, acquiring, absorbing, and using external knowledge to establish new internal knowledge [8; 30; 38; 39; 41; 42].

In a dynamic environment, up-to-date knowledge is required to strengthen technological capabilities. Strategic blind spots can be eliminated through interactive learning between individuals and/or organisations, and an organisation's self-capacity can be enhanced by acquiring external knowledge. This information can then be employed for product development, manufacturing process improvement, and organisational decisions [4; 14; 32].

To engage in innovation activities, an organisation must enhance its technology commercialisation capability by frequently acquiring external complementary knowledge. These knowledge assets must then be absorbed and transformed into innovation activity capabilities. However, for organisations endeavouring to enhance their learning capacity to improve their commercialisation abilities, the technology commercialisation duration may be prolonged by the organisation's tendency to emphasize the transform of absorbed knowledge into commercialised products. Thus, we infer that the organisational learning capacity significantly influences the feasibility of technology commercialisation.

H2: Organisational learning capability influences the feasibility of technology commercialisation.

3) Integration capacity. To successfully commercialize a technology, technology push and market pull strategies must be assessed. In other words, marketing must be integrated with R&D information [9; 10; 16]. Therefore, during innovation activities, greater integration of information regarding the external market and internal technological development facilitates the formulation of strategies. When the new technologies created by an organization's internal innovation activities cannot satisfy market demands, the organization must identify complementary technologies to supplement its inefficiencies in the process from invention to commercialization. By contrast, if a new technology accommodates external market demands, the company can promptly conduct commercialization to reduce the time required to introduce new products to the market. Thus, we argue that integration capability significantly and positively influences the technology commercialization decisions.

H3: Higher organisational integration capability increases the feasibility of technology commercialisation.

4) Reconfiguration capability. Reconfiguration refers to an organization's ability to apply its self-developed technology to various products or markets in differing geo-graphical regions. For example, in the 1970s, because of the increasing costs of developing the digital private automatic branch exchange, Northern Telecom continuously promoted the technology to additional markets in wider geographical regions. Furthermore, this technology was applied to different systems. Similar strategies of applying core technologies to various products can be observed for enterprises such as Honda, Canon, Sony, and HP [17; 27].

Numerous uncertainties can be addressed by the organisation conducting innovation activities. For example, product demands may differ according to specific consumer groups. Therefore, an organisation must adjust its commercialisation process, or even overhaul its manufacturing process, to satisfy various consumer demands. In addition, after a technology is invented by the research unit, the organisation may reassign employees to different departments to form a project team for commercialising the technology. Thus, increased reconfiguration capabilities can facilitate patent commercialisation. We contend that reconfiguration positively influences technology commercialisation decisions; that is, reconfiguration positively influences the feasibility of technology commercialisation.

H4: Higher organisational reconfiguration capability increases the feasibility of technology commercialisation.

5) Complementary assets. The goal of profiting from in-

novations can only be attained through commercialisation. However, not all organisations have the capability to introduce products to the market. An R&D-orientated laboratory, for example, devotes its core capabilities to research and development; thus, its capabilities for developing marketing strategies or marketing surveys regarding consumer behaviour are comparatively insufficient. Hence, for this laboratory, self-introducing new products to the market is extremely risky. The solution to facilitate successful technology commercialisation is the adoption of complementary assets (capabilities) that compensate for an organisation's deficiencies. Organisations rarely possess all the capabilities required for commercialisation, particularly small- and medium-sized enterprises. To commercialise a specific innovation technology, if an organisation does not possess adequate manufacturing capabilities, complimentary technologies provided by other organisations may be required for production. However, because these complimentary technologies may have already been patented, a company capable of transforming technologies into new products or services may encounter a lack of marketing channels. Thus, increasing complementary assets is crucial for technology commercialisation [36; 37]. This process requires substantial time and capital, which small enterprises that depend on external investments to finance commercialisation may lack [20; 36].

In recent years, the resources or knowledge required for innovation have become increasing complex and interdisciplinary. Enterprises now demand various means to acquire complimentary resources or knowledge. Teece [37] contended that commercialisation can only be achieved with other complimentary assets. Complimentary technologies, distributors, and competitive manufacturers and services may serve as critical complementary assets during commercialisation. For example, because enterprises incur significant expenses and high risks during technology commercialisation, an enterprise may rely on services provided by other companies to assess the feasibility of commercialising a certain technology. External professional risk assessments provide more valuable advice to enterprises [29]. In addition, to reduce investment risks, the government may offer funds to assist enterprises in conducting technology commercialisation [36].

The number of researchers investigating the importance of complementary assets for companies is increasing. For example, Tripsas [40]indicated that in the typesetter industry, existing companies survive under the threat of aggressive innovation because of the complementary assets they possess. Gans and Stern [15]asserted that a company's negotiation power can be improved by possessing complementary assets. Rothaermel [33] reported that existing pharmaceutical companies acquired several crucial complementary assets by forming alliances with newly established biotechnological companies to profit from innovation. Therefore, we argue that whether a company possesses complementary assets influences the feasibility of commercialisation.

H5: Complementary assets possessed by an organisation positively and significantly influence the feasibility of technology commercialisation.

In addition, we argue that whether a company is located in a science park may be crucial to the duration and success of commercialisation. Considering companies located in science parks as an example, a complete supply chain increases the availability of the complimentary assets required by companies. This system enables more sufficient information to be obtained, and the connexion between active inventors in science parks may influence the efficiency of technology commercialisation [6].

H6: Whether an organisation is located in a science park positively and significantly influences the feasibility of technology commercialisation.

III. METHODOLOGY

This study adopted the Cox proportional hazards model as the empirical model for survival analysis. Survival analysis is primarily used to model the duration of a specific event. This tool compiles time data based on respondents' reflection of the event to formulate predictions. In addition, because the time of a specific event is always positive, the data may not be normally distributed; thus, the traditional methods of least squares and regression equations are not applicable. Survival analysis typically uses the hazard function to identify the connexion between specific hazard factors or variables and their survival time. If we are certain that the hazard rate is represented by a specific function that increases, decreases, increases then decreases, or does not change over time, we can define the hazard function as an exponential, Weibull, or lognormal model. However, in standard circumstances, the precise function cannot be determined; thus, the Cox proportional hazards model (or Cox regression model) is commonly adopted to construct a survival model.

A. Cox proportional hazards model

This study adopted the Cox proportional hazards model to establish a survival model for the duration of technology commercialisation and related factors. The Cox proportional hazards model can be presented as

$$h(t|X,\beta) = h_0(t) \times e^{\sum_{i=1}^{p} \beta_i X_i} \quad (1)$$

where, $h_0(t)$ denotes the baseline hazard function; β_i is the to-be-estimated parameter corresponding to independent variable *i, i* = 1,2,…,*p*; and X_i is the i_{th} independent variable, *i* = 1,2, . . . *p*.

Considering *n* technology samples awaiting commercialisation, k samples are commercialised during the observation period, and (n-k) samples are censored data. The survival time of k samples is presented by $t_{(1)}<t_{(2)}<\ldots<t_{(k)}$. $R_j = R(t_{(j)})$ denotes the risk set at time $t_{(j)}$. The event occurrence or censored time of any sample point $l\ (\in R_j)$ in this risk set are equal to or greater than $t_{(j)}$. This set includes the technologies that are still owned and not censored. We selected the partial likelihood function suggested by Cox as the

parameter values for the model, as shown in Formula (2):

$$L(\beta) = \prod_{j=1}^{k}(e^{X_{(j)}\beta}/\sum_{l\in R_j} e^{X_l\beta}) \quad (2)$$

where $X_{(j)}$ is the vector of the independent variable for a technology to be commercialised at time $t_{(j)}$ (including the previously mentioned p independent variables). β is the corresponding vector of the to-be-estimated parameters. In addition, applications of individual variables or a combination of model variables typically employ the hazard ratio (HR) to compare the hazard rate of event occurrence for different variables. The definition of HR is expressed as Formula (3):

$$\widehat{HR} = \frac{\hat{h}(t|X^*,\hat{\beta})}{\hat{h}(t|X,\hat{\beta})} = e^{\sum_{i=1}^{p}\hat{\beta}_i(X_i^*-X_i)} \quad (3)$$

$X^* = (X_1^*, X_2^*, \dots, X_p^*)$ and $X = (X_1, X_2, \dots, X_p)$ represent two sets of vectors of independent variables. $\widehat{HR}$、$\hat{h}$、$\hat{\beta}$ denote the HR, hazard function, and estimated value of parameters, respectively. After two sets of independent variable vectors are determined, the fixed hazard ratio between these two sets is obtained. In Formula (3), if $\widehat{HR}$ >1, the variable SetX^* has a greater hazard rate for technology commercialisation than Set X, meaning that the estimated survival time before the technologies in SetX^* are commercialised is shorter than that in Set X.

B. Variables

1) Time variable. The time variable in this study was the duration of commercialisation. We defined the commercialisation duration as the time from the announcement of a technology patent to the commercialisation of the technology. The duration was measured in months. Because a company may commercialise its technologies through more than two means, we selected the earliest means adopted for commercialisation as the starting point of the event. In this study, the end of the observation was December 2008. Because the sampled company that responded to our questionnaire had already commercialised its patents, we adopted uncensored data by selecting patents that were commercialised before December 2008 as the analysis samples.

2) Independent variables. We designed the questionnaire to include a five-point Likert scale. The questionnaires were distributed to R&D business superintendents. Each independent variable is explained below.

a) *Sensing.* By sensing, related market information is thoroughly investigated based on potential demands and the analysis of competitor behaviour. This assists the organisation in predicting opportunities and responding to threats, and can even filter, rectify, and more accurately predict market responses to organisational strategies. In addition, the development of future technologies is more easily forecasted if the organisation frequently explores new knowledge [8; 11; 38]. In this study, the operational definition of sensing was the degree of market information collected and used by an organisation to commercialise its patents.
b) *Learning.* Learning is the capability to organisationally understand external knowledge and establish useful internal knowledge. In addition, this capability assists an organisation in assessing, acquiring, absorbing, and using external knowledge to establish new internal knowledge [8; 30; 38; 39; 41; 42]. In this study, the operational definition of learning was the degree of knowledge related to patent commercialisation learned by the organisation employees.
c) *Integration.* Integration refers to the capability to organise information of the external market and the internal technologies [9; 10; 16]. In this study, the operational definition of integration is the capability to integrate inter-functional information for an organisation to perform innovation activities such as patent commercialisation.
d) *Reconfiguration.* Reconfiguration is the capability for an organisation to apply its core technology to various products or markets in differing geographical regions. This goal can be achieved through changes in the organisational structure [27]. In this study, the operational definition of reconfiguration is an organisation's ability to reallocate useful resources for innovation activities.

IV. RESULTS

This study referenced the international patent numbers in Appendix A of OST-INPI/FhG-ISI, including G01N033, A61P, C12, A61K, A01H, A01N, C07, A01P, C40B, and A61Q. The inventors and assignees of these patents are all of Taiwanese nationality. Thus, we designed our retrieval strategy for biotechnological patents as ((ACN/tw AND ICN/tw) AND (ICL/G01N033 OR ICL/A61P OR ICL/C12 OR ICL/A61K OR ICL/A01H OR ICL/A01N OR ICL/C07 OR ICL/A01P OR ICL/C40B OR ICL/A61Q OR ICL/C07)). The sample for this study was Taiwanese biotechnological patents issued and announced by the United States Patent and Trademark Office (USPTO) during 1998 and 2007. Questionnaires were distributed to the target participants who were the assignees named in patent documents submitted by businesses in the industry.

Using Patent Guider 2.0, we obtained 636 biotechnological patents. Fig. 1 shows the patents issued from 1998 to 2007 for six categories of biotechnology: biotechnology, organic chemistry, pharmaceutics and cosmetics, bio-detection, agriculture and food, and biomedical engineering. Fig. 2 shows the assignees according to industries, academic organisations, and research institutions. The results suggest that most patents are owned by research institutions and industries, and that research institutions possess more patents than individuals and academic and industrial organisations. In the last decade, research institutions have led the development of technologies.

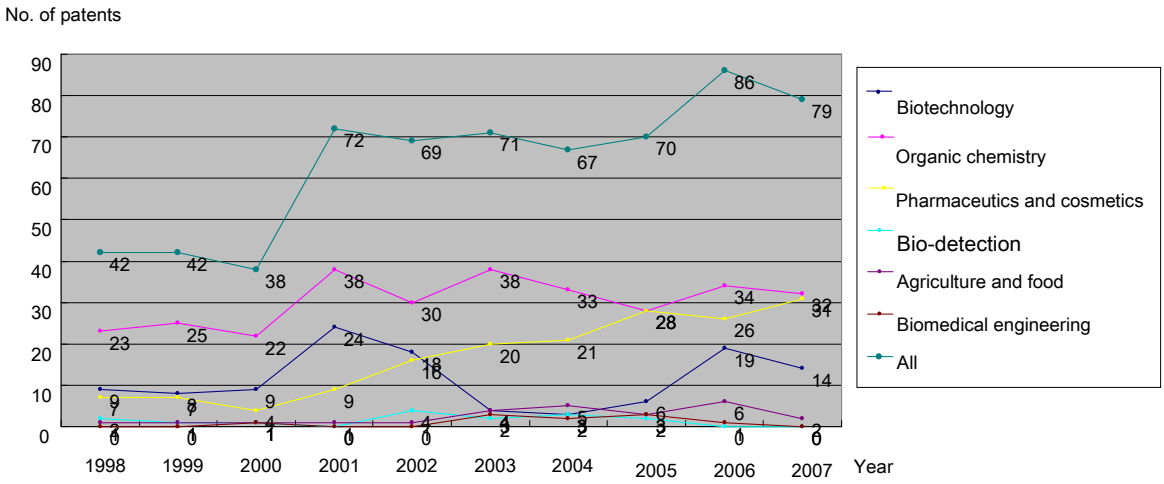

Fig. 1. Biotechnological patents issues in the last 10 years

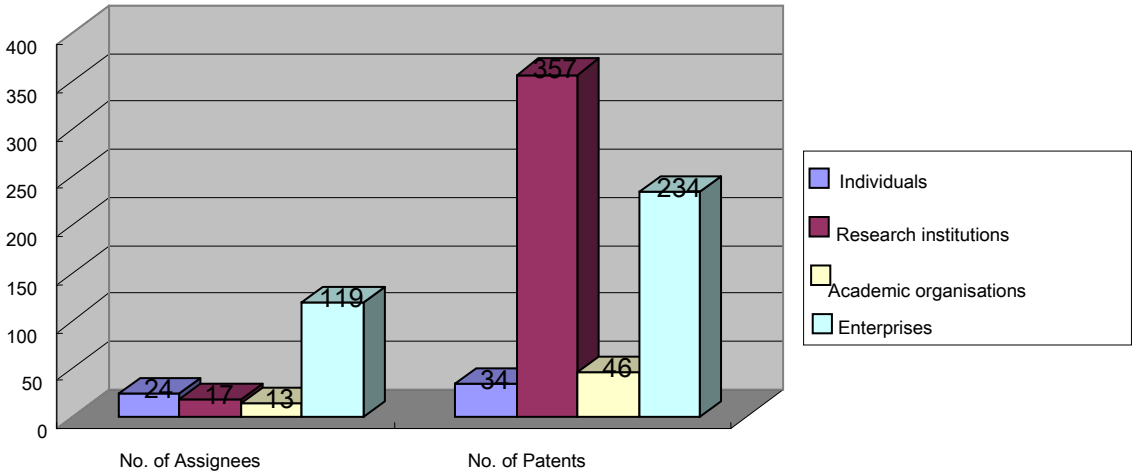

Fig. 2. Biotechnological assignees divided into categories and the corresponding numbers of patents

The target subjects of this study were companies in the biotechnology industry. The reason we excluded research institutions, which have led the development of technology, was that these institutions are non-profit organisations; thus, their primary purpose is not yielding profits through commercialisation of innovation activities. Thus, we only distributed a total of 119 questionnaires among the superintendents of biotechnological companies. Because patent information can reveal trade secrets, a non-disclosure agreement was attached to the questionnaires to increase the response rate. The number of valid questionnaires returned was 28, for a 23.53% response rate.

A. Sampled companies

All the companies that responded, apart from one that was supported by governmental funds, obtained their capital investments from domestic venture capital (11), domestic businesses (20), and domestic individual shareholders (28). This suggests that domestic shareholders and businesses express greater interest in the biotechnological industry compared to venture capital firms. Regarding the average scale, the sampled companies were typically medium and small enterprises. The average paid-in capital for each company was 205 million dollars, and each company employed an average of 84 employees. For more than 80% of these companies, over half of their employees were specialized in the field of biotechnology, with 20 companies reporting that 75% of their employees specialized in biotechnology. The target markets of the biotechnological products manufactured by these companies were not restricted to specific regions; instead, they were distributed globally.

B. Biotechnology commercialisation

This study defined patent commercialisation as the use of various methods, including authorising, selling, transferring, and introducing, to develop processes, manufacture products, and establish new entities. Statistical data show that most companies that owned biotechnological patents commercial-

ised their patents by self-implementing the patents in manufacturing processes or products; only a few companies commercialised their patents through authorisation and cooperation. The majority of companies (25) commissioned patent representatives to manage their biotechnological patents, followed by the companies that commissioned venture capital firms, managerial consultants, attorneys, and accountants. Only three companies did not commission external experts to assist in patent management. Of our sample, only three companies completed commercialisation within one year. The remaining 25 companies spent more than one year conducting patent commercialisation, and 4 companies even spent longer than three years.

C. Reliability and validity analysis

Reliability analysis is a tool for evaluating the reliability and coherence of questionnaire questions. This study adopted Cronbach's alpha for reliability analysis. Nunnally [28] contended that questions with a reliability value between 0.5 and 0.75 are acceptable. According to standard principles, we employed convergent validity and discriminant validity for analyses. Convergent validity was used to examine the significance of the factor loadings in each question and dimensions that were to be measured. Convergent validity over 0.6 could be considered significant. Discriminant validity was analysed using the method proposed by Anderson and Gerbing [2], who limited the path parameters of any two dimensions to 1 (constrained model). A chi-squared difference test was then performed on the constrained model and the unconstrained model. If the chi-squared value of the constrained model is significant and greater than that of the unconstrained model, discriminant validity exists between the two dimensions.

Before performing reliability analysis, confirmatory factor analysis (CFA) was conducted to analyse the relationship between the questions and the dimensions. In addition, to determine the convergent validity between the questions and the dimensions, following CFA, questions with insufficient factor loadings for convergence was eliminated (< 0.6). Table 1 shows the factor loadings and the reliability coefficients after several questions were deleted.

After several questions were deleted, the reliability coefficients of the four major dimensions were 0.691, 0.597, 0.754, and 0.601, respectively, indicating that the questionnaire results were reliable. The convergent validity of the refined questions exceeded 0.6, indicating that all dimensions achieved convergent validity.

Table 2 shows the results of the chi-squared difference test and the chi-squared values of the constrained and unconstrained model in each dimension. The chi-squared difference in all dimensions achieved a 0.001 level of significance, which indicated that the dimensions could be easily discriminated from each other and would not be integrated. Therefore, superior discriminant validity was found for the questions and scales in this study.

TABLE 1. RELIABILITY AND VALIDITY ANALYSIS

Dimension	Question	Reliability coefficient	Convergent validity coefficient (factor loading)
Sensing	S2	0.691	0.841
	S3		0.641
	S4		0.705
	S5		0.693
Learning	L3	0.597	0.609
	L4		0.711
	L5		0.904
Integration	I1	0.754	0.896
	I3		0.896
Reconfiguration	R1	0.601	0.691
	R2		0.675
	R3		0.868

TABLE 2. DISCRIMINANT VALIDITY ANALYSIS

Dimension	Constrained model (chi-squared value)	Unconstrained model (chi-squared value)	Chi-squared difference testing
Sensing↔Learning	68.7	40.4	28.3***
Sensing↔Integration	134.2	96.3	37.9***
Sensing↔Reconfiguration	167.3	126.3	41***
Learning↔Integration	136	95.8	40.2***
Learning↔Reconfiguration	148.4	101.5	46.9***
Integration↔Reconfiguration	129.5	96.4	33.1***

*** $\Delta\chi^2 > 10.8000, p < .001$

Before analysing the survival model, we used correlation matrices and goodness-of-fit to examine the correlations between variables, whether collinearity existed, and whether our data were applicable to the Cox proportional hazards model.

D. Correlation matrix

This study used the Pearson's product-moment correlation matrix to conduct a correlation analysis. Table 3 shows the Pearson's product-moment correlation coefficients between independent variables. These coefficients indicated that a positive and significant correlation exists between S2 (the organisation allocates specific staff or departments to collect industry information to assist organisational decision-making), S3 (the organisation creates a database based on customer responses) (r = .618, $p < .05$), and S4 (the organisation can rapidly obtain complete information of the biotechnology market) (r = .418, $p < .1$). This correlation indicated that if an organisation was more inclined to allocate staff or departments to perform specific tasks, the organisation was more likely to record customer responses, market information, and internal technology information in its database. Furthermore, the organisation had a higher likelihood of obtaining complete information. S3 (the organisation creates a database of customer responses) was negatively and significantly correlated to R1 (the organisation follows procedures for human resources deployment that flexibly deploy its employees) (r = -.392, $p < .1$). This correlation indicated that if an organisation was more inclined to create a database of customer responses, it was less likely to deploy its employees flexibly. S4 (the organisation can rapidly obtain complete information of the biotechnology market) was positively and significantly correlated to S5 (the organisation duly obtains information of industry competitors) (r = .524, $p < .05$) and L4 (employees in the organisation acquire relevant occupational skills through group discussions) (r = .686, $p < .05$). S5 (the organisation duly obtains information of industry competitors) was positively and significantly correlated to L5 (inter-departmental learning and communication in the organisation) (r = .508, $p < .05$). L5 (inter-departmental learning and communication in the organisation) was positively and significantly correlated to I3 (the organisation integrates relevant industry information to develop new products) (r = .425, $p < .1$). I1 (the organisation is completely aware of the differing demands of the biotechnology market and internal technologies) was positively and significantly correlated to I3 (the organisation integrates relevant industry information to develop new products) (r = .605, $p < .05$). I3 (the organisation integrates relevant industry information to develop new products) was positively and significantly correlated to R2 (the organisation has a convenient and rapid channel for communicating with related cooperating firms) (r = .472, $p < .1$). R1 (the organisation follows procedures for human resource deployment that flexibly deploy its employees) was positively and significantly correlated to R3 (the organisation periodically implements minor adjustments in response to environmental changes) (r = .443, $p < .1$). R2 (the organisation has a convenient and rapid channel for communicating with related cooperating firms) was positively and significantly correlated to R3 (the organisation periodically implements minor adjustments in response to environmental changes) (r = .428, $p < .1$). Collinearity was not achieved because none of the correlation coefficients between questions exceeded 0.7, as shown in Tables 4 to 7.

E. Analysis of the Cox proportional hazards model

This study reduced the question dimensions and transformed the selected choices in each questionnaire into factor scores for the dimensions. Subsequently, we employed these scores for analysis using the Cox proportional hazards model.

Before we conducted the analysis using the Cox proportional hazards model, we examined whether the combined factor scores varied over time. The results suggested that factor scores for each dimension were not influenced by time; therefore, adopting the Cox proportional hazards model was reasonable.

TABLE 3. PEARSON'S PRODUCT-MOMENT CORRELATION MATRICES FOR SENSING, LEARNING, INTEGRATION, AND RECONFIGURATION CAPABILITIES

	S2	S3	S4	S5	L3	L4	L5	I1	I3	R1	R2	R3
S2	1											
S3	**.618****	1										
S4	**.418***	.090	1									
S5	.332	.171	**.524****	1								
L3	-.032	-.055	.101	**.439***	1							
L4	.206	.063	**.686****	.291	.048	1						
L5	.102	-.093	.318	**.508****	**.430***	**.514****	1					
I1	-.023	-.040	.261	.140	.186	.198	.227	1				
I3	.291	.135	.201	.198	.048	.325	**.425***	**.605****	1			
R1	-.051	**-.392***	.058	.014	.050	.076	.119	-.049	.164	1		
R2	-.085	-.018	.012	-.301	-.178	.275	-.033	.156	**.472***	.132	1	
R3	.168	.133	.066	-.169	-.017	.334	.102	-.012	.244	**.443***	**.428***	1

*$p < .1$, **$p < .05$

Without differentiating event characteristics, this study regarded various means including authorisation, selling, transferring, introduction to manufacturing processes and products, and the establishment of new entities as unique events of commercialisation. Subsequently, we employed the Cox proportional hazards model to construct a survival model for companies during the commercialisation of biotechnology. Dynamic capabilities and complimentary assets were set as the independent variables for Model I in Table 4, and the additional control variable "Science Park" was included in Model II.

As shown in Table 4, the likelihood of Model I was $118.821 > \chi^2_{5,0.05}$, which indicates that not all model parameters were 0. The sensing and integration capabilities in dimensions reached 0.1 and 0.05, respectively, both are significant results. The calibration parameter (B) for sensing capability was 0.579, and an EXP (B) greater than 1. This implied that superior sensing capabilities significant increased the feasibility of patent commercialisation, which corresponded to the research hypothesis. Calibration parameter (B) for integration was 0.563, and has an EXP (B) greater than 1. This indicated that superior integration capabilities significantly increased the feasibility of patent commercialisation, which corresponded to the research hypothesis.

The likelihood of Model II was $118.821 > \chi^2_{6,0.05}$, which indicated that not all model parameters were 0 and this model was significant. This model was affect by the addition of the control variable "Science Park." Excluding the integration capability, which did not significantly influence the feasibility of patent commercialisation, as shown in Model I (H4 was rejected); the other capabilities in Model II positively and significantly influenced patent commercialisation ($p < .1$). The calibration parameter (B) for sensing was 0.797, and the EXP (B) was greater than 1. Similar to Model I, this indicated that superior sensing capabilities increased the feasibility of an organisation commercialising a patent (H1 was supported). The calibration parameter (B) for learning capability was 0.826, and the EXP (B) was greater than 1. This implied that superior learning capabilities significantly increased the feasibility of an organisation commercialising a patent, which corresponds to the research hypothesis (H2 was supported). The calibration parameter (B) for integration capability was 0.677, and the EXP (B) was greater than 1. This implied that superior integration capabilities significantly increased the feasibility of an organisation commercialising a patent, corresponding to the results produced by Model I (H3 was supported). Comparing to organisations that possessed no additional capabilities, organisations capable of manufacturing, developing new products, and marketing exhibited greater patent commercialisation feasibility. This type of organisation possessed a calibration parameter of 1.23, which suggested that organisation that have these three capabilities are 3.421 times more likely to commercialise its patents compared to an organisation that does not have these capabilities. These results indicate that the possession of complimentary assets positively and significantly influences the feasibility of patent commercialisation ($p < 0.1$), which supports H5. In addition, an organisation located in a science park had a calibration parameter of 1.517, which suggested that this organisation was 4.559 times more likely to commercialise its patents compared to organisations not located in a science park. Thus, we verified that being located in a science park positively and significantly influenced the feasibility of patent commercialisation.

V. CONCLUSIONS AND SUGGESTIONS

A. Research findings

Few studies have employed a comprehensive theoretical framework to investigate the influence that organisational capabilities have on the commercialisation of technology. Thus, in addition to establishing a more complete theoretical framework, this study adopted the complimentary assets that influence profits, as proposed by Teece [37] in *Profiting from Technological Innovation*, which considered the complimentary asset factors in both dynamic capabilities and profits from innovation and analysed the influence that patent indicators have on patent termination using public patent information. Our literature review indicated that most previous studies regarding the influence that organisational behaviours have on innovative performance selected only one capability for empirical research. However, from the perspective of organisations, more than one capability exists. Therefore, this study employed dynamic capabilities and key complimentary assets for organisations to analyse innovation performance. Our verification results showed that three dynamic capabilities, that is, sensing, learning, and integration, significantly influenced the feasibility of patent commercialisation. We also verified the argument proposed by Teece [37] that complimentary assets positively and significantly influence the commercialisation of biotechnology patents. Science parks are areas where information spreads rapidly. The results of this study showed that companies located in a science park were more likely to commercialise their patents compared to companies that were not located in science parks.

B. Academic contribution

Most previous studies of dynamic capabilities investigated the factors that formed dynamic capabilities, although researchers have not agreed on the precise definitions of each capability. Thus, this study clarified each capability according to the characteristics of the biotechnology industry to establish a structure of dynamic capabilities appropriate for the industry.

In addition, although previous research related to dynamic capabilities focused on the definitions of dynamic capabilities and organisational performance, empirical studies of these topics are scare. Most studies that employed organisational capabilities to investigate organisational innovation performance analysed only one capability and assessed innovation

TABLE 4. COX PROPORTIONAL HAZARDS MODEL

	Model I			Model II		
	B	SE	Exp(B)	B	SE	Exp(B)
Sensing	.579	.302	**1.784***	.797	.332	**2.219****
Learning	.531	.336	1.700	.826	.360	**2.285****
Integration	.563	.267	**1.757****	.677	.274	**1.968****
Reconfiguration	-.184	.294	.832	-.283	.306	.754
Manufacturing*Marketing*New product development	.209	.501	1.233	1.230	.714	**3.421***
Science park	-	-	-	1.517	.675	**4.559****
-2 log likelihood	118.821			113.048		
Chi-squared value	16.927			21.568		
p value	.005			.001		

* Calibrated parameters in the model differed from 0 at a significance level of 0.1
** Calibrated parameters in the model differed from 0 at a significance level of 0.05
*** Calibrated parameters in the model differed from 0 at a significance level of 0.01

performance from the perspective of innovation profits. For the biotechnology industry, which is R&D-oriented, objectivity may be sacrificed if performance is assessed through profits. Therefore, we used innovation speed as the basis for analysing the feasibility of patent commercialisation. A more complete capability structure—dynamic capabilities—was also integrated for analysis. We first conducted survival analysis of the individual capabilities that form dynamic capabilities. Then, based on the concept that dependencies exist in organisational dynamic capabilities, we conducted survival analysis of every capability already formed. The analytical results verified that several hazard factors influence the feasibility of patent commercialisation.

C. Empirical implications for management

Currently, biotechnological products have not achieved popularity among Taiwanese consumers, who have varying demands for such products. During innovation activities, biotechnological firms must integrate market information related to consumer demands with internal technology developments. In addition, the integrated information should be introduced into the firm's knowledge management system. This process benefits biotechnological firms when developing new products and can prevent business resources from being unnecessarily wasted on developing products that do not satisfy consumer demands.

Biotechnological firms in Taiwan must endeavour to catch up with firms in developed countries. To establish a firm position in the epistemic and economic system, a company's exclusive capabilities must evolve continually to face an uncertain environment. Specifically, for biotechnology, which is based on rudimentary sciences, domestic companies should value the commercialisation of rudimentary sciences through external and internal integration and learning and the development of exclusive core competencies. For the development of dynamic capabilities, this study contends that organisations should adopt open business models instead of traditional self-sustaining organisational models. For example, an organisation may participate in seminars or speeches organised by academic and research institutions to understand developmental trends or inspirations.

The continued formation of information through inertia is critical for organisational development. Organisational capabilities necessitate the accumulation of employees' personal experience. An organisation should transform the experience or knowledge of model employees into explicit assets that can be sampled by the remaining employees. Because an organisation's project team is typically grouped for new product development, marketing, and rudimentary research activities, we contend that the recorded details of each project can provide a reference for similar activities conducted in the future, thereby facilitating organisational operations.

D. Limitations and suggestions

The concept and structure of dynamic capabilities have not matured. According to Teece, Pisano and Shuen [39], dynamic capabilities include learning, reconfiguration, and integration. Teece, Pisano and Shuen [39] also discussed organizational assets and positioning and the concept of path dependence. However, the scope of structure they proposed was too expensive to serve as a complete theoretical structure. Thus, this study roughly categorised dynamic capabilities into sensing, learning, integration, and reconfiguration to investigate the influence that these capabilities have on the commercialisation of biotechnology patents by domestic biotechnological organisations.

Because of the gradual erosion of industry boundaries, we recommend that future studies examine the influence that novel managerial styles employed by biotechnological firms have on organisational innovation from the perspective of open business models. Furthermore, we anticipate the elucidation of how open business models, unlike traditional self-sustaining models, alter existing learning organisations.

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APPENDIX A

OST-INPI/FhG-ISI TECHNOLOGY NOMENCLATURE

Technology Field	IPC CODE
I. Electricity - Electronics	
Electrical devices-electrical engineering	F21;GO5F;HO1B,C,F,G,H,J,K,M,R,T;H02;H05B,C;F,K
Audiovisual technology	G09F,F;G11B;H03F,G,J;H04,-003,-005,-009,-013,-015,-017,R,S
Telecommunications	G08C;H01P,Q;H03B,C,D,H,K,I,M;H04B,H,J,K,L,M;H04B,H,J,K,L,M,N -001,-007,-011,Q
Information technology	G06;G11C;G10L
Semiconductors	H01L
II. Instruments	
Optics	G02;G03B,C,D,F,G,H;H01S
Analysis, measurement, control	G01B,C,D,F,G,H,J,K,L,M,N,P,R,S,V,W;G04;G05B,D;G07;G08B,G;G09B, C,D,;G12
Medical engineering	A61B,C,D,F,G,H,J,L,M,N
III. Chemicals, pharmaceuticals	
Organic fine chemistry	C07C,D,F,H,J,K
Macromolecular chemistry, polymers	C08B,F,G,H,K,L;C09D,J
Pharmaceuticals, cosmetics	A61K
Biotechnology	C07G;C12M,N,P,Q,R,S
Materials, metallurgy	C01;C03C;C04;C21,C22,B22
Agriculture, food	A01H;A21D;A23B,C,D,F,G,J,K,L;C12C,F,G,H,J;C13D,F,J,K
IV. Process engineering	
General technological processes	G10B,D (whithout -046 to -053), F,J,L;B02C;B03;B04;B05B;B06;B07;B08,F25J;F26
Surfaces, coating	B05C,C,D;B32;C23;C25;C30
Material processing	A41H;143D;A46D;B02B;B26;B29;B31;C03B;C08J;C14;D01;D02;D03;D0 4B,C,G,H,J,L,M,P,Q;D21
Thermal processes and apparatus	F22;F23B,C,D,H,K,L,M,N,Q;F24,F25B,C,J;27;F28
Chemical industry and petrol industry, basic materials chemistry	A01N;C05;C07B;C08C;C09B;C,F,G,H,K;C10B,C,F,G,H,J,K,L,M;C11B,C, D
Environment, pollution	A62D;B01D -046 to -053;B09;C02;F01N;F23G,J
V. Mechanical engineering, machinery	
Machine tools	B21;B23;B24;B26D,F;B27;B30
Engines, pumps, turbines	F01B,C,D,K,L,M,P;F02;F03;F04;F23R
Mechanical elements	F15;F16,F17,G05G
Handling, printing	B25J;B41;B065B,C,D,F,G,H;B66;B67
Agricultural and food machinery and apparatus	A01B,C,D,F,G,J,K,L,M;121B,C;A22;A23N,P;B02B;C121;C13C,G,H
Transport	B60;B61;B62;B63B,C,H,J;B64B,C,D,F
Nuclear engineering	G01T;G21;H05G,H
Space technology, weapons	B63G;B64G;C06;F41;F42
VI. Consumer goods, civil engineering	
Consumer goods and equipment	A24;A41B,C,D,F,G;A42;A43B,C;A44;A45;A46B;A47;A62B,C;A63;B25B, C,D,F,G,H;B26B;B42;B43;B44;B68;D04D;D06F,N;D07;F25D;G10B,C,D, F,G,H,K
Civil engineering, building, mining	E01;E02;E03;E04;E05;E06;E21