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Exploring the Influential Factors of Cluster Cooperation in Taiwan's Biotechnology Industry

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Abstract. In recent years, numerous countries around the world have continually devoted substantial efforts to the biotechnology industry. Despite its endeavors over two decades, Taiwan's biotechnology industry has not yet made any remarkable achievements. In this study, influential factors of cooperation in the biotechnology industry are discussed from the perspectives of cluster cooperation and interaction. Using the analytic hierarchy process and quantitative results obtained from in-depth expert interview questionnaires, the weights of various influential factors are investigated and analyzed, which could provide a reference for future research and resource allocations. The influential factors of cluster cooperation in Taiwan's biotechnology industry can be categorized into four major factors and sixteen sub-factors. The results indicate that among all of the factors that impact cluster cooperation in the biotechnology industry, "enterprise innovation ability" is the most critical. The innovation capacity of cooperative partners is always considered a priority in cluster cooperation among enterprises, whereas research and development (R&D), personnel quality, and the R&D environment are the most crucial sub-factors within the primary dimension of enterprise innovation ability. This finding is consistent with the fact that a biotechnology product is closely bound to innovative R&D, from its initial development stage to the eventual clinical launch. Factors of secondary importance include business management ability and government resource utilization, which suggests that the principal activities associated with cluster cooperation in the biotechnology industry depend heavily on an enterprise's business management ability and are inextricably linked to government resource utilization.
Keywords. Biotechnology industry, Cluster cooperation, Taiwan, Analytic hierarchy process (AHP).
JEL. C22, O40, O43.

1. Introduction

Because biotechnology is highly technological, has great market potential, provides high added value, and is characterized by low levels of pollution and energy dependency, and because personalized medical demands are rapidly increasing due to population growth and aging, countries worldwide have adopted biotechnology as a state policy to improve people's health and well-being and have made substantial investments in this industry, leading to a powerful trend of biotechnology development. Globally, the United States has the most developed biotechnology industry, which is characterized by large capital investments in and assiduous management of R&D in the bioscience, biomedicine, and biotechnology

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fields. In the private sector, people's enthusiasm for and active investments in biotechnology are also remarkable. In addition to the highly stable infrastructure, relevant supporting measures have facilitated the increase in biotechnology companies' initial public offerings. The overall performance of this industry, including the number of biotechnology companies and product programs approved by the Food and Drug Administration, makes the biotechnology industry in the United States an undisputed leader in this field.

In contrast to advanced Euro-American countries, Taiwan is considered a follower, rather than a leader, in terms of the key techniques adopted by its protein pharmaceutical industry. For Taiwan to be ranked among the leading countries in biotechnology, its protein pharmaceutical development musttake advantage of the government's comprehensive goal-oriented R&D plans. Taiwan made a delayed entry into the field of biotechnology; indeed, this field was not included among the major future scientific and technical projects promoted by large-scale R&D plans until the 1980s. Since then, biotechnology-associated departments and research institutes have been established to nurture biotechnology talents and accumulate energy for Taiwan's biotechnology R&D. A comprehensive set of promotional measures have been implemented, including techniques, talents, capital, legislation, clinical trials, technology transfers, and incubator zones, providing a superior environment for biotechnology development. Today, the infrastructure required for biotechnology development has been established. The R&D energy of research institutes can play a role in biotechnology development through the mechanisms of technology transfer and incubation. Relevant techniques developed by upper- and middle-reach enterprises can be smoothly transferred to lower-reach enterprises for commercial exploration and to further promote technology in the global market. Organizations that are primarily responsible for technology promotion include universities and central research institutes, which conduct fundamental innovation research; the Department of Health, which designs and implements regulations and policies; the Ministry of Economic Affairs (MOEA), which commercializes and industrializes technologyand encourages investment; and certain specialized organizations that promote particular technologies, such as the Council of Agriculture.

To investigate the structure of biotechnology industry development, the characteristics of the biotechnology industry that distinguish it from general industry are considered, including the long development processand the significant business management challenges encountered from early R&D to product launch. In addition, influential factors are discussed from the perspective of the supply of and demand for cluster cooperation in the biotechnology industry.

In previous research, the performance of the biotechnology industry is mainly explored from the perspective of government policies. A limited number of studies have discussed the relationship between biotechnology industry development and the factors that influence this development based on biotechnology industry cluster cooperation. This research aims to use quantitative data to explore the correlation, importance, and disadvantages of factors that impact the development of the biotechnology industry for the purpose of providing a reference to aid decisionmaking by relevant organizations. The objectives of this study are to investigate the influential factors of cluster cooperation in Taiwan's biotechnology industry, to analyze the mutual impacts of these factors using the analytic hierarchy process (AHP), and to identify the critical factors in the government's decisionmaking.

2. Literature review

2.1. The status quo of the biotechnology industry

To stimulate the development of biotechnology- and pharmaceutical-related industries and to improve people's health and social well-being, Taiwan's Industrial Development Bureau, MOEA, uses a relatively broad definition of biotechnology and pharmaceuticals. This definition encompasses three major sections: the pharmaceutical industry, the medical device industry, and the applied biotechnology industry. The pharmaceutical industry essentially comprises pharmaceuticals, including Western medicines, biologics, traditional Chinese medicines, and active pharmaceutical ingredients. The medical device industry is divided into various sections based on function and application: diagnostic and monitoring; surgical and therapeutic; assistive and compensation; in-vitro diagnostics; prevention and health promotion; and miscellaneous. The applied biotechnology industry mainly involves product R&D and manufacturing using biotechnology but also includes the provision of services for pharmaceutical exploration. Its industrial projects include agricultural, food, specialty, environmental, and contact biotechnology projects. The breakdown of Taiwan's biotechnology industry from 2013 to 2014 is presented in Table 1.

Table 1. *Breakdown of Taiwan's biotechnology industry from 2013 – 2014 (Unit: NTD (100 million)*

Industry	Applied biotechnology industry		Pharmaceutical industry		Medical device industry		Total	
Year	2013	2014	2013	2014	2013	2014	2013	2014
Revenue	782	822	824	832	1,163	1,232	2,769	2,886
Number of enterprises	490	500	350	350	761	781	1,601	1,631
Number of employees	17,540	18,340	19,000	19,000	35,040	36,429	71,580	73,769
Export value	299	312	196	197	484	513	979	1,022
Import value	495	500	992	999	605	615	2,092	2,114
Domestic sales: export sales	62:38	62:38	76:24	76:24	58:42	58:42	65:35	65:35
Demand of domestic market	978	1,010	1,620	1,634	1,284	1,334	3,882	3,978

Data source: Medical and Pharmaceutical Industry Technology and Development Center, Biotechnology and Pharmaceutical Industries Promotion Office, MOEA, 2015.

2.2. Biotechnology industry

The former Vice President of the United States, Al Gore, who won the Nobel Peace Prize in 2007, described in his book "The Future: Six Drivers of Global Change" the emergence of a new set of revolutionary and powerful biological, biochemical, genetic, and material science technologies launched by scientists that would allow us to observe, explore, describe, modify, and control biological cells and enable the genetic information of living cells to flow between each other, even across species boundaries. Creating a new body part with three-dimensional (3D) printing could satisfy people's unmet medical needs. Protein pharmaceuticals are competitively developed to cure diseases, including diabetes, cardiovascular diseases, cancer and rare diseases. Nanoscale-precision robot techniques that can control the measurement of brain waves and integrate the applications of the human brain, computer interface, material science, and nanotechnology could transform a human being's life, from birth until death.

Given the need toachieve sustainable development, biotechnology has already been universally regarded as a critical field forsolving various global challenges, such as emerging infectious diseases, inadequate food supply, limited water resources, climate extremalization, and the need for preventive medicine, in addition to enhancing environmental consciousness. In the future, new medical demand situations are expected in Taiwan, which may involve prospective medicine and integrated medical services using big data. For example, organ transplantation using 3D printing technologies, the treatment of disease with newlydeveloped protein pharmaceuticals, early predictionsregarding physical health using big data analysis, the provision of preventive medical services based on area warnings of potential infectious diseases, and synchronous transmission of individual medical diagnostic information to hospitals before a first-aid patient arrives. In addition, as the population ages and birth rates decline, the medical and pharmaceutical requirements triggered by the relevant age care are gradually increasing, leaving no time to improveor develop the biotechnology industry.

Applications of biotechnology tend to be diversified, ranging from food supply to the exploration of the human lifecycle, including birth, aging, illness, and death. In particular, the occurrence, treatment, and prevention of human diseases are an important focus of biotechnology. Numerous countries have proposed strategies and plans for biotechnology industry development. The biotechnology development guidelines proposed by various countries are described below; notably, all of them involve cluster cooperation.

1) The United States is a pioneer in the global biotechnology industry. Its first biotechnology company, Genentech, was established in 1976 and has a 41-year history. Genentech flourished due to the United States' early policies to promote the biotechnology industry, including the federal government's massive investment budget for the biotechnology industry; strict biotechnology regulatory mechanisms; laws and incentive measures designed to promote technology transfer and commercialization; local governments'efforts to attract the entry of new enterprises; and a liberalized market economy. Among these policies, the investment by the federal government, local governments' efforts to attract new entry, and the laws and incentive measures to promote technology transfer and commercialization involve cluster cooperation among biotechnology enterprises. Enterprises increase R&D energy through cluster cooperation, which ensures that their demands are taken seriously and assists them in obtaining solutions.

2) Talavyria *et al.,* (2015) suggested to the German Bioeconomy Council (GBC), which had conducted a bioeconomy analysis, that the German government should focus on the following issues to develop the biotechnology industry: a) breaking traditional barriers and strengthening communication between science, commerce, and politics; b) creating bioeconomy R&D funds to reward performance benchmarks; c) implementing regulations that supported the biotechnology industry, from R&D to technology transfer and marketing, to promote the development and application of emerging technologies; d) establishing R&D funds, providing incentives (such as favorable tax policies) to encourage private investment, and easing the laws on capital investment; and e) strengthening R&D (new technology communication), product development, and market internationalization. Germany presents a typical case of a government that aggressively promotes the biotechnology industry, which drives industry improvement and leads cluster cooperation. The biotechnology industry cannot act without interacting with other organizations, including companies, government agencies, universities, and research institutes. Due to the diversity of resources demanded in the biotechnology industry during the development process, from R&D to fabrication and marketing, a single enterprise cannot accomplish any step independently. Cluster cooperation not only promotes energy accumulation but also expandsthe scope of activities conducted by an enterprise. In sum, cluster cooperation among enterprises involves multiple areas and objects and thus business management ability is a crucial factor for evaluating cluster cooperation.

3) France's main policies to promote the biotechnology industry include the following: aggressively developing biological medicine and strengthening biotechnology R&D, easing relevant laws, and providing financial support and tax incentives. These measures significantly promote the rapid proliferation of biotechnology start-ups. In addition to fundamental studies, France focuses on the stimulation of industry-academy cooperation, decentralization of technological achievements, acceleration of internationalization, improvements in the investment environment, and revisions to relevant regulations. Cluster cooperation between enterprises has flourished under the government's leadership and promotion. The associated amalgamation of capital, regulations, and the environment is an indispensable factor in cluster cooperation among biotechnological enterprises from initial R&D to technology transfer and international cooperation. Cluster cooperation enhances an enterprise's professionalism and expands its network.

Consequently, the utilization of government resources is a crucial element in the evaluation of cluster cooperation.

4) The development of China's biotechnology industry is mainly led by the government and thus differs from the marketmechanism-oriented development of the industry in the United States. China's development policies include anemphasis on scientific and technical R&D, the cultivation of flagship enterprises, intensification ofinternational competitiveness, encouragement of foreign investment and factory establishment, and strengthened administrative approval and supervision processes. Cluster cooperation among enterprises is conducted under the management and control of the government. Unlike Western countries, which are characterized by freeeconomies, the government in China plays a leadership role in scientific and technical R&D, regulation counseling, and internationalization. Thus, the evaluation of cluster cooperation primarily depends on the policy indexes.

5) In addition to a national development strategy for the biotechnology industry, Japan has devised other policies, such as the jointgeneration of development strategies by organizations, an emphasis on fundamental research, the determination of major development fields, intensification of the integration of R&D and industry acceleration, improvements in international competitiveness, the cultivation of a venture capital industry, the construction of infrastructure for biotechnology development, the relaxation of various censorship standards, and the nurturing of human resources. Japan has paid close attention to R&D innovation and the construction of its infrastructure.

6) Taiwan's biotechnology industry is still considered a follower. To fill the critical gap in industrial development, the Taiwanese government implemented the Taiwan Diamond Action Plan for Biotech Takeoff. The primary aims of this plan are to improve the commercial energy of R&D institutions, strengthen the exploitation of pharmaceutical and medical devices, attract capital to the industry, and promote cluster formation in the biotechnology industry using integration and incubation mechanisms and the energy of regional industries and research institutes. The strategy is to transform Taiwan into an Asia-Pacific hub for the development of biotechnology and pharmaceutical industries. It is estimated that by the end of the year 2025, 20 new pharmaceuticals will be developed, 80 niche medical devices will be listed in overseas markets, and 10 flagship brands of biotechnology and health services will be created. Future promotion of Taiwan's biotechnology industry will focus on the intensification of biotechnology, encouragement of innovative R&D, promotion of the commercialization of biotechnology and pharmaceutical industries, the strengthening of pharmaceutical administration and counseling, activation of biotechnology venture capital, and enhancement of incubation and cluster development. The promotion of the biotechnology industry emphasizes acceleration of biotechnology transfer and the fortification of the energy of the incubation cluster. The successful development of the biotechnology industry in various countries around the world shows that cluster cooperation plays an important role. Therefore, exploring the factors that influence cluster cooperation can assist in revealing the sources of development, whichmakes the objective of this study even more significant.

2.3. Influential factors of cluster cooperation in the biotechnology industry

From the early stages of R&D topic identification, enterprises within the biotechnology industry need to communicate with research institutes and R&D organizations to ensure the accuracy and feasibility of technological R&D standards. In the clinical test stage, enterprises mustengage in cluster cooperation with medical and inspection institutions to guarantee the effectiveness and consistency of developed products. Subsequently, at the product launch stage, business management requires the introduction of financial, tax, and legal support, intellectual property protection, and marketing to meet business development needs in different stages. Cluster cooperation is generally presented in a diversified manner and involves research institutes, government agencies, medical institutions, and business management units. The influential factors of cluster cooperation in the biotechnology industry are described below.

2.3.1. Enterprise innovation ability

As indicated by Bien *et al.* (2014), the biotechnology industry differsfrom other industries and must increase the value of innovative R&D through R&D interaction among enterprises in the early stages, particularly under the considerations of R&D risk sharing and cost savings. Montalvo (2011) discovered that cluster knowledge innovation and transfer and intellectual property protection are the major factors that impact cluster cooperation. Introducing advanced R&D innovative techniques into the system from overseas research institutes is highly beneficial to industry development. The knowledge absorptive capacity and social network proliferation mechanisms that are involved in the process are clearly related to the growth of knowledge innovation capacity. Hu & Hung (2014) noted that in developing countries, research results -particularly innovative achievements in high-technology industries- must be protected. Okamuro & Nishimura (2015) proposed that among all factors that influence the fundamental conditions for international cluster cooperation, the concept of innovation capacity is the most important andthus should be considered first in cluster cooperation. Innovation capacity, including R&D, technology transfer, and international cooperation, should be the chief priority for enterprises in cluster cooperation and can reflect the performance of the network. Hsu *et al.* (2015) found that influential factors for technology transfer in universities include the energy and creativity of the founder and entrepreneur, the experience of the entrepreneur, the social network, patent diversification experience, and the innovative energy of research evidence and the design prototype, all of which indicate that enterprises engaged in cluster cooperation with colleges and universities should aim to improve their internal creativity. In other words, enterprises can enhance R&D energy by engaging in cluster activities with international research institutes, which reflects the overall performance of their innovation capacity.

2.3.2. Government resource utilization

Governments tend to enhance the biotechnology industry through various measures taken from different perspectives, including nurturing talent, raising capital, assisting R&D technology, and incubating business start-ups. In this manner, enterprise growth is stimulated and industry development is promoted. Okamuro & Nishimura (2015) indicated that Germany, Japan, and France promote cluster cooperation through national policies. Cluster cooperation has benefitted from substantial privileges and subsidies from the governments of these countries and is clearly organized to implement their respective policies. Hsu *et al.* (2005) suggested that governments could promote and improve the overall development environment through various policies, such as enhancing the education system to foster talent, revising the operation procedures of scientific and technical R&D institutions, updating the information network to perfect infrastructure, directly participating in new product purchases, contracting for research plans, and indirectly setting an import tariff, to effectively influence the supply side of industrial innovation. Using taxation, regulations, preferential measures, and financial indexes, governments can impact biotechnology industry development. Hence, the overall development of biotechnology companies cannot be achieved without the use of government resources. Therefore, the use of resources provided by the government to enterprises pursuing certain achievements through interaction with others is a crucial influential factor in cluster cooperation. Government resource utilization can signal that an enterprise has passed the government's screening mechanism and that it possesses the ability to complete tasks commissioned by the government, revealing – to a certain extent – its superiority over other enterprises.

2.3.3. Business management ability

Bien *et al.* (2014) indicated thatthe development process is very long for both the biotechnology industry and biotechnology products. Moreover, most enterprises that need to interact with other enterprises, research institutes, and government departments to share risk and costsdue to limited resources are small and mediumenterprises. Relevant activities during such interactions include strategic allianceswith research institutes to ensure R&D technology transfer, vertical integration with upstream and downstream enterprises, and application for government tax benefits and R&D subsidies. In short, all internal and external cluster activities related to business management are encompassed by this range. Therefore, industrial cluster cooperation is extremely common. Limited by the fact that the biotechnology industry mainly comprises small and mediumenterprises, Taiwan lacks the resources to handle businessother than R&D. Hence, the Taiwanese government directly and indirectly provides incubation center services to the biotechnology industry to ensure that industrial requirements are met. For example, the Nankang Biotech Incubation Center (NBIC), which is conveniently located in the Nankang Software Park of Taipei, integrates the abundant surrounding resources, including the biotechnology center, Academia Sinica, and multiple large-scale teaching hospitals and research institutes in North Taiwan, to achieve the cluster addition effect. This center provides a good cultivating and counseling environment for the initiation and development of Taiwan's biotechnology industry. In particular, the NBIC provides biotechnology start-ups with public spaces, such as clean rooms, negative-pressure rooms, precisioninstrument rooms, and sterile culture rooms, to satisfy the specific environmental requirements of biotechnology R&D. In addition, the center offers enterprises full access to communal facilities and equipmentto reduce the burden and risk of the entrepreneurial process. With the accumulation of the energies mentioned above, enterprises can gradually strengthen their internal business management energy, which differs from that of non-biotechnology industries. This internal business management energy plays a critical role in the business of future start-ups and is an important factor in cluster cooperation.

2.3.4. Mutual trust

Cooke *et al.* (1997) suggested that learning, trust, dependence, exchange, and internal cooperation are crucial factors in the innovation system that exists between regions. This system is generally conducted through regional integration associated with certain cultural foundations in a particular region. Bien *et al.* (2014) indicated that during the process of knowledge exchange and resource sharing, R&D companies are often at risk of leaks or theft of confidential information. Therefore, mutual trust between partners has become a significant topic in cluster cooperation.

In the past decade, the importance of R&D cooperation between enterprises has escalated, particularly for innovation in technology-intensive fields such as the biotechnology industry. The pursuit of borderless innovation has become an important strategy for maintaining a competitive advantage in this industry. R&D cooperation is regarded as a major means of obtaining crucial resources for enterprises because it not only reduces R&D costs through risk sharing but also helps enterprises to acquire necessary technical information and to improve R&D efficiency through information exchanges with different organizations. Compared to other industries, the biotechnology industry relies more on R&D cooperation due to long development cycles and the enormous costs associated with its inherent high-risk nature and its knowledge- and capital-intensive characteristics. Therefore, effective approaches for gaining external resources have become crucial for the survival of the biotechnology industry, leading to a general trend of technical cooperation among enterprises and organizations. Mutual trust is critical for smooth cooperation, which is reflected through mutual communication and interaction andadded value sharing. Successful cooperation will eliminate distrust, and mutual trust between organizations will increase the flexibility of cooperation between them. Mutual trust is universally established through acquaintances and interactionsassociated with R&D cooperation, including exclusive authorizations, formal contracts, and informal communications.

In summary, enterprise innovation ability, government resource utilization, business management ability, and mutual trust are the most crucial factors for the success of Taiwan's biotechnology industry and thus are the major focus of this study.

3. Research methods

3.1. Research framework

The structure for the initial stage of this study is established based on the literature discussed in Section 2, and the operative definitions of various factors are explained in this section. The overall dimension is divided into four sub-dimensions that reflect the influential factors of cluster cooperation in Taiwan's biotechnology industry, namely, enterprise innovation ability, government resource utilization, business management ability, and mutual trust. Enterprise innovation ability includes four sub-dimensions: number of patents (intellectual property), R&D personnel qualities, R&D environment, and R&D network. Government resource utilization encompasses talent training, research technology transfer mechanisms, R&D incentive measures, and business incubation and counseling. Business management ability contains three sub-dimensions: degree of internationalization, intellectual property management flexibility, and financial improvement capacity. Mutual trust comprises three parts, namely, corporate culture, executive capacity, and cooperation network. Figure 1 shows the research framework of the first stage.

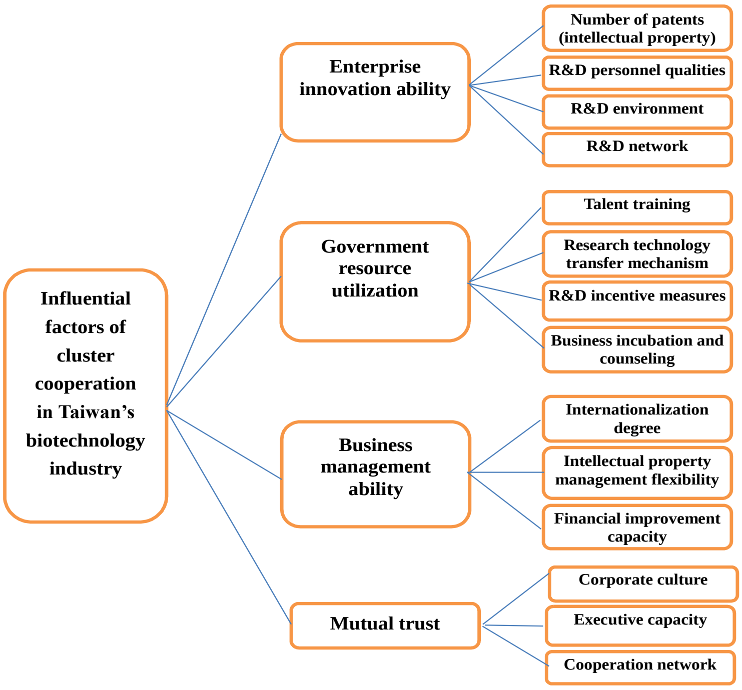

Figure 1. *First-stage hierarchy framework*

3.2. Expert interviews

To explore the influential factors of cluster cooperation in Taiwan's biotechnology industry, expert interviews are conducted based on the factors obtained from the framework literature in Section 3.1 in order to determine the applicability of the crucial factors and adjust them within the framework. The expert interviews are described in detail below. First, the companies to be interviewed are introduced.

3.2.1. Company A

Established in 2002, Company A is an OTC (over-the-counter)-based company engaged in new drug R&D. This company's priority is to meet unsatisfied medical demands in the fields of anti-cancer and anti-infection pharmaceutical development. Its primary approach to obtain technical sources is cluster cooperation with international research institutes that possess progressive technologies. Company A has a high-level business management team, a commendable overall management energy, and an anticipated niche. Based on its own experience, the company suggests that a high-level business management team should be included as a subsequent layer of business management ability in this research framework because it is considered one of the most crucial sub-factors.

3.2.2. Company B

Company B was founded in 1993 and subsequently listed. This companyfocuses primarily on developing new pharmaceuticals, improving biotechnology standards, and producing high-quality drugs at reasonable prices in the international market. Company B strongly agrees with the inclusion of the degree of internationalization as a sub-factor in the business management ability dimension of cluster cooperation.

3.2.3. Company C

Established in 2013, Company C devotes itself to the development of technologies for innovative antibody drugs. Cooperating with multiple industry-education organizations, this company has produced new antibody drugs and entered the global market. Company C strongly agrees that enterprise innovation ability is the most important influential factor for cluster cooperation in Taiwan's biotechnology industry and emphasizes that enterprise R&D personnel qualities are the touchstone of an enterprise's innovation ability.

3.2.4.Company D

Founded 13 years ago, Company D mainly provides services to the biotechnology industry by accepting commissions to conduct research on toxicology, pathology, and simple pharmacology. It has experimental animal rooms for studies on toxicity and sub-acute, acute, and functional dietary supplements. In the value chain of biotechnology industry development, Company D belongs to the service industry for pre-clinical tests. Based on its experience with business management, Company D believes that government resource utilization is the dominant determinant of an enterprise's development environment and of the range and depth of its cluster cooperation.

3.2.5.Company E

Company E works with natural minerals, which are nanonized using advanced technologies in the R&D of biotechnology products and drug delivery platforms, and focuses on anti-cancer drugs for restraining disease development. It expects to provide more efficient and safe medicines to patients, improving their quality of life. The company maintains that mutual trust is a significant factor in cluster cooperation with international enterprises.

3.2.6.Organization F

Established in 1996, Organization F executes and promotes policies for biotechnology industry development and acts as a bridge for communication, coordination, and integration among departments to construct a complete development environment for the biotechnology industry. This organization provides orientation for Taiwan's biotechnology industry development, facilitates international interactions in the industry, and operates as a mediator and coordinator of cluster cooperation. Organization F emphasizes that global vision is imperative in industrial cluster cooperation and that Taiwan's biotechnology industry should aggressively target the international market for both R&D and listing.

3.2.7.Organization G

Organization G focuses mainly on generating a superior cultivation environment and promoting biotechnology incubation policies through the efficient integration of multiple types of resources, including spaces, instruments and equipment; R&D techniques; fundraising; business services; and management counseling. To improve the cluster cooperation environment of the biotechnology industry, this organization provides necessary assistance to enterprises, helping them to meet the periodic requirements of biotech enterprise management.

3.2.8.University H

University H is a distinguished university established in 1976 in Taipei and comprises a medical university and an affiliated hospital. The medical university attaches great importance to the transfer of research technology and is very positive about interacting with enterprises, research institutes, and hospitals. In addition, University Hpossesses abundant practical experience in cluster cooperation between upstream and downstream organizations.

3.2.9.Organization I

Organization I is a non-profit organization that was established through government and public donations in 1984. It aims to construct the necessary environment and infrastructure for the development of Taiwan's biotechnology industry by developing critical biotechnology and fostering and recruiting professional talent through cooperation with enterprises, the government, universities, and research institutes.

Table 2. *Information about interviewed experts*

Interviewed company	Seniority	Title
Company A	28yrs	President
Company B	25yrs	General manager
Company C	25yrs	General manager
Company D	25 yrs	General manager
Company E	25yrs	Deputy general manager
OrganizationF	18 yrs	Senior manager
OrganizationG	15yrs	Senior manager
UniversityH	20yrs	Dean
Organization I	25yrs	Director

The results of the expert interviews reveal that experts hold differing opinions on the utilization of government resources but agree that the biotechnology industry requiresextensive involvement in laws and regulations. Enterprises must adhere to various laws and regulations from the early stages of product development for R&D security. However, the government must offer counseling services to enterprises at each stage of R&D and manufacturing in order to promote industrial development. Therefore, the utilization of government resources in the form of regulatory counseling is an important sub-factor that impacts cluster cooperation among biotechnology enterprises. Moreover, regarding the business management ability factor, the experts believe that the experience and performance of a high-level business management team significantly influence an enterprise's long-term positioning and business model and thus constitute a major sub-factor of business management. The expert interview results show that two factors described above (government resource utilization and business management ability) are influential in cluster cooperation in Taiwan's biotechnology industry. The research framework proposed above is revised accordingly and presented as Figure 2.

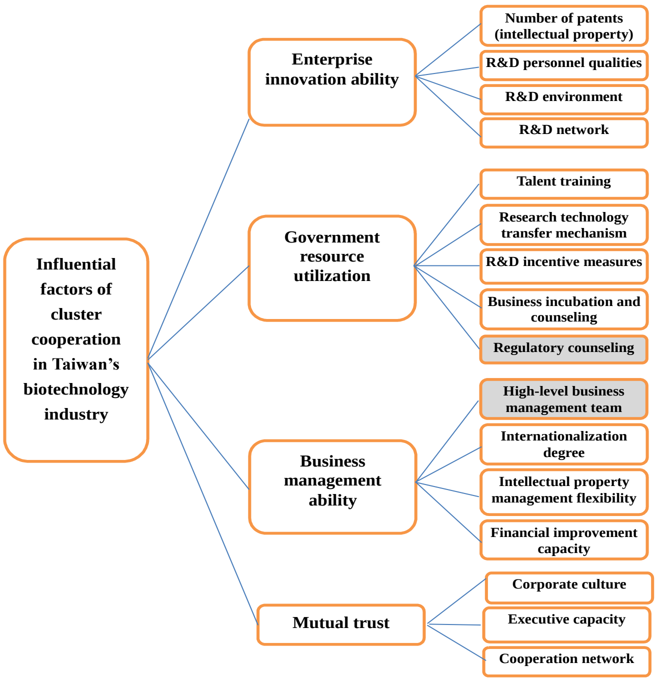

Figure 2. *Second-stage hierarchy framework*

Table 3 presents the operative definitions of influential factors in cluster cooperation in Taiwan's biotechnology industry.

Table 3. *Operative definitions of influential factors incluster cooperation in Taiwan's biotechnology industry*

Influential factors in cluster cooperation in Taiwan's biotechnology industry	Enterprise innovation ability	Number of patents (intellectual property)	The number of patents for which an enterprise applies to improve the technical distribution.
		R&D personnel qualities	Education and experience of relevant R&D personnel within an enterprise (Huang *et al.,* 2010).
		R&D environment	Software and hardware environments associated with R&D activities within an enterprise (Subramaniam & Youndt, 2005).
		R&D network	Operation of tangible and intangible networks for R&D cooperation within and outside an enterprise (Drejer & Jorgensen, 2005).
	Government resource utilization	Talent training	Training (organized by the government) of the talent to promote industry development and reduce academy-industry disparities.
		Research technology transfer mechanism	Measures implemented by the government to smoothly transfer R&D achievements from universities and research institutes to enterprises for efficient application.
		R&D incentive measures	Preferential measures implemented by the government to stimulate and promote industrial R&D (Bien *et al.,* 2014).
		Business incubation and counseling	Entrepreneurship incubation and business management counseling provided by the government to promote industrial development.
		Regulatory counseling	Regulatory assistance provided by the government to help an enterprise meet requirements in different stages of biotechnology industrial development (Ernst & Young, 2016).
	Business management ability	High-level business management team	Executive officers responsible for an enterprise's overall business management (Downs & Velamuri, 2016).
		Internationalization degree	Degree to which an enterprise is valued worldwide by people in the same business during the process between R&D and marketing (Feldman & Francis, 2014).
		Intellectual property management flexibility	Flexibility of an enterprise's management tomaximize the benefits of intellectual property (Su & Hung, 2009).
		Financial improvement capacity	Capacity of an enterprise's management to improve the financial system for sustainable development (Rosson & Mclarney, 2005).
	Mutual trust	Corporate culture	Traits of an enterprise's internal activities (Trippl *et al.,* 2007).
		Executive capacity	Capacity to negotiate operating standards and managerial agreement during cluster cooperation between enterprises (Edquist, 2005).
		Cooperation network	Correlation between enterprises in cooperation (Todtling, & Lehnei, 2006).

3.3. Analytic hierarchy process

AHP is a method used to simplify complex problems of elemental hierarchy. Furthermore, based on the opinions of experts and decision makers for each layer, a pairwise comparison matrix is constructed using the quantified results of the pairwise comparison between the executed elements and a nominal scale. Based on the eigenvector of each matrix and the priority order of the elements in the layers (eigenvectors), the maximum eigenvalue is calculated to evaluate the relative weight of coincident indicator (CI) of the comparison matrix, which provides a reference for decision makers. Generally conducted on a hierarchy with at least three layers, AHP connects all of the layers to calculate the CI and the conformance rate (CR) of the pairwise comparison matrix of the elements between the layers. The results are used to evaluate the consistency of the overall hierarchy. Therefore, in AHP, experts' suggestions are adopted to solve complicated decision-making problems and the comparison matrix and eigenvector are applied to determine relativeweight-associated problems that impact elements between the layers (Saaty, 1980).

3.4. Research objects and data collection method

The research objects of this study include a number of entities in Taiwan's biotechnology industry. A questionnaire survey is conducted on senior(five+ years), middle and topmanagers of enterprises, the government, universities, and research institutes in the biotechnology industry. Completed questionnaires are collected in paper form and by email without disclosing the managers' names. During the survey, the investigation objective and questionnaire content are presented to the interviewed experts to guarantee the validity and recovery rate of the questionnaires. In the questionnaires that are designed to collect experts' ideas, five evaluation measures of AHP are set on a nine-layer hierarchy, namely, equally important, slightly important, very important, extremely important, and absolutely important, as shown in Table 4.

Table 4. *Evaluation measures*

Evaluation measure	Definition	Instructions
1	Equally important	Contributions of two indicators are of equal importance – equally important.
2	Evaluation measure is between 1 and 3	Compromised value is between the evaluation measures 1 and 3.
3	Slightly important	Slightly inclined toward a certain scheme based on experience and judgment – slightly important.
4	Evaluation measure is between 3 and 5	Compromised value is between 3 and 5.
5	Very important	Fairly inclined toward a certain scheme based on experience and judgment – very important.
6	Evaluation measure is between 5 and 7	Compromised value is between 5 and 7.
7	Extremely important	Strongly inclined toward a certain scheme in practice – extremely important.
8	Evaluation measure is between 7 and 9	Compromised value is between 7 and 9.
9	Absolutely important	An indicator is sufficiently proved to be important – absolutely important.

Data source: Zhengyuan Deng, Guoxiong Zeng (1989).

4. Research results

In this study, an investigation is conducted using AHP by collecting questionnaire responses from executive managers and experts in the biotechnology industry. Based on the results, the weights of various factors are statistically obtained. Thus, the research results can be deduced based on the influential degree of each factor's weight.

4.1. Basic information obtained through questionnaires

In this study, 25 questionnaires are sent to the research objects, including executive managers and experts in Taiwan's biotechnology industry. Twenty usable responses are collected from the 21 recovered responses, for a recovery rate of 80%, as presented in Table 5. Regarding service seniority, managers with seniority between five and 10 years, between 11 and 15 years, and greater than 15 years account for 35%, 40%, and 25% of respondents, respectively (Table 6). Table 7 provides an overview of experts' titles.

Table 5. *Summary of questionnaire collection*

Questionnaire information	Sample number	Percentage
Distributed questionnaires	25	100%
Recovered questionnaires	21	84%
Invalid questionnaires	1	4%
Valid questionnaires	20	80%

Table 6. *Service seniority of interviewed experts*

Service seniority	Sample number	Percentage
5-10 yrs	7	35%
11-15 yrs	8	40%
>15 yrs	5	25%
Total	20	100%

Table 7. *Expert titles*

Affiliated enterprise or organization	Title
A Governmental industry-promotion organization 1	Senior manager Yang
B Governmental industry-incubation organization 2	Manager Chen
C Governmental organization 3	Team leader Chung
D Governmental organization 4	Section chief Lin
E Governmental organization 5	Section chief Lin
F Legal entity 1	Manager Juan
G Legal entity 2	Manager Lin
H Legal entity 3	Deputy manager Gao
I Legal entity 4	Senior associate researcher Tsai
J Legal entity 5	Researcher Chiang
K Biotech pharmaceutical factory 1	Manager Gao
L Biotech pharmaceutical factory 2	Manager Gao
M Biotech pharmaceutical factory 3	Deputy manager Lai
N Biotech pharmaceutical factory 4	Deputy manager Shih
O Biotech pharmaceutical factory 5	Manager Chang
P University professor 1	Professor Lan
Q University professor 2	Professor Wu
R University professor 3	Professor Chen
S University professor 4	Professor Hsu
T University doctoral student 5	Student Wang

4.2. AHP results

In this study, "Expert Choice 2000" software is used as the AHP tool to calculate the weight of each influential factor in cluster cooperation. The AHP expert questionnaire presented in Table 8 provides statistical data for each factor's weight. The overall weight (priority weight) is relative to the product of primary and secondary dimensions. The order of the dimensions can be obtained from the magnitude of the overall weights.

Table 8. *Weight analysis of each dimension using AHP*

Primary dimension	Secondary dimension	Overall weight	Ranking
Enterprise innovation ability 0.428	Number of patents (intellectual property)	0.086884	3
	R&D personnel qualities	0.171628	1
	R&D environment	0.092448	2
	R&D network	0.076612	5
Government resource utilization 0.155	Talent training	0.02511	15
	Research technology transfer mechanism	0.0599	16
	R&D incentive measures	0.036425	12
	Business incubation and counseling	0.038905	11
	Regulatory counseling	0.035185	14
Business management ability 0.278	High-level business management team	0.07367	6
	Internationalization degree	0.053098	9
	Intellectual property management flexibility	0.065608	7
	Financial improvement capacity	0.085624	4
Mutual trust 0.139	Corporate culture	0.041283	10
	Executive capacity	0.061438	8
	Cooperation network	0.036279	13

To discuss the weight of the primary dimensions of influential factors, namely, enterprise innovation ability, government resource utilization, business management ability, and mutual trust, the weights and ranking of the four primary dimensions must be calculated using the statistical results of the AHP expert questionnaires. Table 9 shows the pairwise comparison matrix and CI of the four dimensions.

Table 9. *Pairwise comparison matrix of the primary dimensions*

	Enterprise innovation ability	Government resource utilization	Business management ability	Mutual trust	Overall weight	Ranking
Enterprise innovation ability	1	3.217994	1.879443	2.131081	0.428	1
Government resource utilization	0.310753	1	0.577114	1.300954	0.155	3
Business management ability	0.532073	1.732761	1	2.557109	0.278	2
Mutual trust	0.469246	0.768667	0.391067	1	0.139	4

In the framework of influential factors for cluster cooperation in Taiwan's biotechnology industry, theresults of this research indicate that the top layer includes enterprise innovation ability, government resource utilization, business management ability, and mutual trust. Enterprise innovation ability has the greatest weight, followed by business management ability and government resource utilization, whereas mutual trust has the lowest weight among the four factors. As shown by the results, enterprise innovation ability is the most important influential factor in cluster cooperation in the current biotechnology industry. Enterprise innovation ability and business management ability are the main forces behind biotechnology activities and reflect the primary characteristics of R&D innovation and business models in the biotechnology industry. Government resource utilization also has certain effects on the development of the biotechnology industry, particularly for biotechnology start-ups, whose growth from R&D to commercialization depends heavily on government assistance for cost savings and to accelerate commercialization. Hence, government resource utilization is an essential factor in cluster cooperation. Moreover, mutual trust plays an indispensable role in integrating the relevant factors and improving the efficiency of cluster cooperation in Taiwan's biotechnology industry.

Secondary dimension analysis involves various sub-factors of the four primary dimensions of enterprise innovation ability, government resource utilization, business management ability, and mutual trust.

1) Weight and ranking analysis of influential factors under the primary dimension of enterprise innovation ability

There are four sub-factors under the primary dimension of enterprise innovation ability: number of patents (intellectual property), R&D personnel qualities, R&D environment, and R&D network. Table 10 presents the pairwise comparison matrix and weight ranking of the sub-factors of enterprise innovation ability.

Table 10. *Pairwise comparison matrix of the secondary dimensions*

	Number of patents (intellectual property)	R&D personnel qualities	R&D environment	R&D network	Hierarchical weight	Overall weight	Ranking
Number of patents (intellectual property)	1	0.66052301	1.0344285	0.793835014	0.203	0.086884	3
R&D personnel qualities	1.5139518	1	2.4555006	2.2790256	0.401	0.171628	1
R&D environment	0.966717371	0.407248933	1	1.7376689	0.216	0.092448	2
R&D network	1.2597076	0.438784014	0.575483626	1	0.179	0.076612	4

The results reveal that R&D personnel qualities, with a weight of 0.401, significantly impact enterprise innovation ability, followed by R&D environment and number of patents (intellectual property), with weights of 0.216 and 0.203, respectively. R&D network, with a weight of only 0.179, impacts enterprise innovation ability the least. Under the dimension of enterprise innovation ability, R&D personnel qualities and R&D environment are the most crucial factors because biotechnology enterprises are R&D-oriented organizations in which personnel qualities constitute the critical capital of enterprise creativity and an optimal innovation environment allows biotechnology R&D personnel to perform to their maximum potential and create greater cluster benefits. Regarding the number of patents (intellectual property) and R&D network, the former represents enterprise innovation capacity, which can encourage enterprise creativity, whereas the latter reflects the communication and sharing of R&D information, which contributes to enterprise innovation to a certain extent.

2) Weight and ranking analysis of influential factors under the primary dimension of government resource utilization

The primary dimension of government resource utilization includes five influential sub-factors, namely, talent training, research technology transfer mechanism, R&D incentive measures, business incubation and counseling, and regulatory counseling. Table 11 presents the pairwise comparison matrix and weight ranking of the influential sub-factors under government resource utilization.

Table 11. *Pairwise comparison matrix of the secondary dimensions*

	Talent training	Research Technology Transfer mechanism	R&D Incentive measures	Business incubation and counseling	Regulatory counseling	Hierarchical weight	Overall weight	Ranking
Talent training	1	1.1875085	0.866313528	0.61378609	0.639843776	0.162	0.02511	4
Research technology transfer mechanism	0.842099236	1	0.527325924	0.465059282	0.553954719	0.125	0.019375	5
R&D incentive measures	1.1543165	1.8963604	1	1.1125274	1.0646415	0.235	0.036425	2
Business incubation and counseling	1.6292321	2.1502635	0.898854266	1	1.1791476	0.251	0.038905	1
Regulatory counseling	1.5628815	1.8052017	0.939283317	0.84807025	1	0.227	0.035185	3

The results indicate that business incubation and counseling, with a weight of 0.251, is the most important influential factor in government resource utilization, followed by R&D incentive measures and regulatory counseling, with weights of 0.235 and 0.227, respectively. Research technology transfer mechanism, with a weight of 0.162, has the lowest impact among these four sub-factors. In the dimension of government resource utilization, business incubation and counseling has the highest weight because the biotechnology industry is composed mainly of R&D-oriented mediumand small enterprises whose growth -from early R&D to technology commercialization- depends on the government's incubation and counseling and involves patents, laws and regulations, finance, and accounting. R&D incentive measures and regulatory counseling are of secondary importance, because biotechnology is closely associated with people's health and well-being and thus is under intense legal and regulatory supervision. The government usually provides biotechnology enterprises more assistance in the areas of R&D, manufacture, commercialization, and finance through regulations. The low weights of the sub-factorstalent training and research technology transfer mechanism are due to the diversification of the involved fields/organizations and varying levels of emphasis on schools and industrial organizations. In particular, the enterprise's techniques are not obtained only from academic communities and talent training is not provided entirely by the government.

3) Weight and ranking analysis of influential factors under the primary dimension of business management ability

There are four influential sub-factors under business management ability: high-level business management team, degree of internationalization, intellectual property management flexibility, and financial improvement capacity. Table 12 shows the pairwise comparison matrix and weight ranking of the sub-factors under business management ability.

Table 12. *Pairwise comparison matrix of the secondary dimensions*

	High-level business management team	Internationalization degree	Intellectual property management flexibility	Financial improvement capacity	Hierarchical weight	Overall weight	Ranking
High-level business management team	1	1.1131557	1.3931514	0.869113505	0.265	0.07367	2
Internationalization degree	0.898346925	1	0.593114569	0.669416182	0.191	0.053098	4
Intellectual property management flexibility	0.717797075	1.6860149	1	0.670783893	0.236	0.065608	3
Financial improvement capacity	1.1505977	1.493839	1.4907931	1	0.308	0.085624	1

The results show that financial improvement capacity, with a weight of 0.308, is the most important sub-factor in the primary dimension of business management ability, followed by high-level business management team and intellectual property management flexibility, withweights of 0.265 and 0.236, respectively. The least important sub-factor under business management ability is the degree of internationalization, with a weight of 0.191. Financial improvement capacity and high-level business management team have the highest weights, which can be explained by the significant focus of the biotechnology industry on R&D and the fact that the process of developing a new drug from R&D to commercialization is very long (a ten-year development period for a drug is typical) and includes three phases of clinical trials, which require significant capital support. Therefore, sound finance is a prerequisite for an enterprise's existence and a critical sub-factor in cluster cooperation. A high–level business management team with good techniques and a background in international business management is essential for enterprise development, owing to the impact of the business management team on the fate of the enterprise. In contrast, intellectual property management flexibility and the degree of internationalization are strategies adopted by enterprises based on their development.

4) Weight and ranking analysis of influential factors under the primary dimension of mutual trust.

Under the primary dimension of mutual trust, there are three sub-factors, namely, corporate culture, executive capacity, and cooperation network. Table 13 presents the pairwise comparison matrix and weight ranking of the influential sub-factors under mutual trust.

Table 13. *Pairwise comparison matrix of the secondary dimensions*

	Corporate culture	Executive capacity	Cooperation network	Hierarchical weight	Overall weight	Ranking
Corporate culture	1	0.700519456	1.09284	0.297	0.041283	2
Executive capacity	1.4275121	1	1.7592499	0.442	0.061438	1
Cooperation network	0.915047033	0.568424077	1	0.261	0.036279	3

The research results reveal that executive capacity, with a weight of 0.442, is the most influential factor in mutual trust, followed by corporate culture and cooperation network, with weights of 0.297 and 0.261, respectively. Executive capacity has the largest weight because it is the key to quality during technique and product development, which is guided by relevant operational manuals and standard operating procedures. Mutual trust between enterprises and a corporate culture based on entrepreneurship could promote harmony in cluster cooperation and generate comprehensive effects. The cooperation network is a reflection of mutual trust.

5.Conclusions and recommendations

In this study, the influential factors of cluster cooperation in Taiwan's biotechnology industry are discussed. To identify the critical factors, in-depth expert interviews and an AHP expert questionnaire analysis were conducted in the first and second stages, respectively. Based on the continuously growing biotechnology industry in Taiwan, experts in companies, the government, universities, and research institutes proposed key factors in cluster cooperation in the biotechnology industry, indicating that development of this industry depends mainly on the enhancement of enterprise innovation ability, business management ability, government resource utilization and mutual trust among enterprises. The research results make the content of enterprise cluster cooperation more transparent and clarify the energy required for cluster cooperation. The results suggest that government resource utilization should be better managed and that mutual trust among the government, enterprises, universities, and research institutes should be assigned greater value. The situation in Taiwan is similar to biotechnology industry development in Euro-American countries, where enterprises played the role of pioneers and governments provided appropriate support to enterprises during the later stages. All countries around the world must understand the essence of innovation and the capacity to break through existing boundaries using appropriate connections, which is particularly important in the biotechnology industry. Taiwan's biotechnology industry may be in the critical flourishing stage, when enterprise innovation and flexible management are more significant than government resource utilization and mutual trust among enterprises. This phase demonstrates that Taiwan's biotechnology industry is moving out of the initial developing stage and into a new stage of rapid growth.

The influential factors of cluster cooperation in Taiwan's biotechnology industry are explored from the perspectives of various roles in different organizations, including enterprises, the government, universities, and research institutes. The domestic industrial situation is introduced and major schemes to promote industrial development in overseas countries are described to present a range of industrial cluster activities. The results indicate that enterprise innovation ability, government resource utilization, business management ability, and mutual trust are the critical factors that affect cluster cooperation in Taiwan's biotechnology industry. Among these factors, enterprise innovation ability has the greatest impact on enterprise participation in cluster cooperation, followed by business management ability. Accepting the government's resources and strengthening mutual trust in cluster cooperation are also crucial for achieving comprehensive efficiency. The explanation is as follows:

5.1.Enterprise innovation ability

This study reveals that enterprise innovation ability is affected primarily by the number of patents (intellectual property), R&D personnel qualities, R&D environment, and R&D network. Because innovation is the lifeline of biotechnology enterprises, such enterprises have fairly high standards for R&D personnel qualities and pay close attention to in-service training. In the R&D environment, enterprises cannot determine facts and interpret rationality using rigid thoughts; thus, they must adopt more flexible measurement scales and avoid paying too much attention to minor details. In addition, enterprises must accept R&D risks and different opinions in a deliberate manner to avoid stifling creative ideas. An R&D network involves both hardware and software, with the latter referring to extensive connections to educational and research institutes in relevant technical fields for cluster cooperation and conference participation. Regarding technical achievements, enterprises must apply for patents, which are generally regarded as an indicator of enterprise innovation and the basis for judgment by the potential market, to protect their intellectual property.

5.2. Government resource utilization

Research indicates that government resource utilization involves talent training managed by the government, research technology transfer mechanisms, R&D incentive measures, business incubation and counseling, and regulatory counseling. Because enterprises pay great attention to personnel qualities, the government provides on-the-job and professional training to improve the quality of personnel. The course content for such training involves not only the relevant technical fields but also business management, which itself includes laws, accounting, finance, and intellectual property. Training provided by the government has substantially reduced the operating costs of enterprises. To intensify the energy of enterprises to identify R&D topics and to transfer research and technical achievements, the government plays a mediator role to accelerate R&D, helping enterprises to obtain the required technical energy and to accelerate the R&D process. To encourage R&D innovation by enterprises, the government should provide related capital support for talent training and favorable tax treatment of enterprise income. For example, regarding the stock owned by the managers of an enterprise, the government can calculatethe tax based on the market price when the stock is transferred. Biotechnology start-ups are generally active in accessing the various services provided by the government, including incubation counseling, space and entering, raising capital, technology alliances, business opportunity matching, and the acquisition of market information. Even powerful and deep-pocketed biotechnology enterprises are fairly eager to participate in the formulation and modification of regulations, making these topics important to cluster cooperation. The use of government resources provides significant business energy to enterprises.

5.3. Business management ability

One characteristic of the biotechnology industry is innovative R&D. Hence, promoting innovative R&D through business management is a major activity. Promoting innovative R&D requires raising sufficient R&D funds, which leads to different management patterns. For example, when the product development of a biotechnology enterprise reaches a certain stage without mature products, the enterprise can transfer the technology to other companies through technology licensing for a premium. Therefore, the benefits of the biotechnology industry include not only production value but also technology transfer, which is very common in this industry. An enterprise's need for capital is also very important. Enterprises often find themselves with insufficient funds to cover R&D expenses, which compels them to find other sources of financing, such as thedevelopment of biotechnology dietary supplements, to accelerate their cash flow to support new pharmaceutical R&D. This is a different business model that requires a different business management energy. Because the biotechnology industry is closely associated with people's health and well-being, Taiwan's laws and regulations on pharmaceutical development are relatively strict. The regulations must comply with international conventions, such as the inspections required by the pharmaceutical approval agency in the United States. Moreover, the intellectual property of biotechnology enterprises must be protected against infringement by international companies in the same industry. Therefore, the selection of R&D topics in the early stages must be undertaken with great caution. Patent searches and arrangements and compliance with technical regulations are a test of an enterprise's business management energy. To gain access to corresponding incentive measures provided by the government, the business management process should focus on relevant financial and accounting operations, R&D plan writing, personnel training, and participation in international exhibitions and conventions. During the in-depth expert interviews conducted in this study, the senior experts in the biotechnology industry agreed that the activities mentioned above reflect an enterprise's business management capacity, which is crucial for biotechnology cluster cooperation. These expertsmaintained that further improvements in Taiwan's biotechnology industry are necessary to achieve the internationalization of business management energy and thatthe experience and global vision of high-level business management teamsare key factors in this endeavor.

5.4.Mutual trust

Cluster cooperation and communication among enterprises, which are common methods used by enterprises to pursue innovative R&D, require mutual trust as a core value of corporate culture. Rather thanwritten contracts that specify executive details, cooperation within an enterprise and between enterprises (even internationally) depend on corporate culture. A network based on mutual trust is expected to achieve incremental effects of cluster cooperation.

In this study, influential factors of cluster cooperation in Taiwan’s biotechnology industry are discussed. Due to the lack of successfully launched new pharmaceutical products during the present development period, market-oriented correlation is not explored as an influential factor in this research. Rather, this study investigates the relevance of influential factors in cluster cooperation in the biotechnology industry without making any suggestions regarding external market-oriented requirements. Such requirements could be considered in future researchto identify the differences between these two perspectives.

Reference

Bien, H.J., Ben, T.M., & Wang, K.F. (2014). Trust relationship within R&D networks: A case study from the biotechnology industry. *Innovation Management, Policy & Practice*, 16(3), 354-373. doi. 10.1080/14479338.2016.1187574

Cooke, P., Uranga, M.G., & Etxebarria, G. (1997). Regional innovation systems: Institutional and organizational dimensions. *Researh Policy*, 26(4-5), 475–491. doi. 10.1016/S0048-7333(97)00025-5

Downs, J.B. & Velamuri, V.K. (2016). Business model innovation opportunities for the biopharmaceutical industry: A systematic review. *Journal of Commercial Biotechnology*, 22(3), 19–63. doi. 10.5912/jcb735

Drejer, I., & Jorgensen, B.H., (2005). The dynamic creation of knowledge: Analysing public private collaborations. *Technovation*, 25(9), 83-94. doi. 10.1016/S0166-4972(03)00075-0

Edquist, C. (2005). Systems of innovation-perspectives and challenges, *in,* J. Fagerberg, D. Mowery & R. Nelson (Eds). *The Oxford Handbook of innovation*, (pp.181-208). Oxford: Oxord University Press.

Ernst & Young, (2016), *Beyond Borders Returning to Earth*, London: Ernst and Young.

Feldman, M.P. & Francis, J.L. (2003). Fortune favours the prepared region: The case of entrepreneurship and the capitol region biotechnology cluster. *European Planning Studies*, 11(7), 765–788. doi. 10.1080/0965431032000121337

Hsu, W.L., Shen Y.C., Yuan J.C., & Chou C.Y. (2015). Toward successful commercialization of university technology: Performance drivers of university technology transfer in Taiwan. *Technological Forecasting & Social Change*, 92, 25–39. doi. 10.1016/j.techfore.2014.11.002

Hu, M.C., & Hung, S.C. (2014). Taiwan's pharmaceuticals: A failure of the sectoral system of innovation?. *Technological Forecasting & Social Change*, 88, 162–176. doi. 10.1016/j.techfore.2014.06.021

Huang, Y.C., & Wu, Y.C. (2010). Intellectual capital and knowledge productivity: the Taiwan biotech industry. *Management Decision*, 48(4), 580-599. doi. 10.1108/00251741011041364

Montalvo, F. (2011). Economic growth and innovation: Lessons in knowledge sharing from bioscience clusters in Ohio and Puerto Rico. *Global Business and Organizational Excellence*, 31(1), 54-62. doi. 10.1002/joe.21404

Okamuro, H., & Nishimura, J. (2015). Local management of national cluster policies: Comparative case studies of Japanese, German, and French biotechnology clusters. *Administrative Sciences*, 5(4), 213–239. doi. 10.3390/admsci5040213

Rosson, P., & McLarney, C. (2005). Developing clusters in peripheral regions: Biotechnology in Halifax, Nova Scotia, Canada. *Paper presented at the 8th Uddevalla Symposium, Uddevalla*, 15-17 September.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*, New York: McGraw- Hill.

Su, Y.-S., &Hung, L.-C., (2009). Spontaneous vs. policy-driven: the origin and evolution of the biotechnology cluster. *Technological Forecasting Social Change* 76(5), 608–619. doi. 10.1016/j.techfore.2008.08.008

Subramaniam, M., & Youndt, M.A. (2005). The influence of intellectual capital on the types of innovative capabilities. *Academy of Management Journal*, 48(3), 450-63. doi. 10.5465/AMJ.2005.17407911

Talavyria, M.P., Lymar, V.V., & Baidala, V.V., (2015). Improvement of the bioeconomy development analysis instruments: European Union Projects and Germany experience. *Економіка АПК*, 11, 89-95.

Todtling, F., & Lehner, M. (2006). Innovation in knowledge intensive industries: the nature and geography of knowledge links. *European Planning Studies*, 14(8),1035-1058. doi. 10.1080/09654310600852365

Trippl, M., & Tödtling, F. (2007). Developing biotechnology clusters in non-high technology regions -The case of Austria. *Industry and Innovation*, 14(1), 47-67. doi. 10.1080/13662710601130590