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A fuzzy hierarchy integral analytic expert decision process in evaluating foreign investment entry mode selection for Taiwanese bio-tech firms

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ABSTRACT

The purpose of this study is to help bio-tech firms solve the foreign investment (FI) entry mode selection problem. This study combines the concepts of factor analysis, analytic hierarchy process (AHP), genetic algorithm (GA), and fuzzy integral to construct an entry mode selection approach.

This study produces several interesting findings. (1) In the different investment entry modes, there are large differences in evaluation focus when investors select their entry modes. (2) For example, Taiwanese bio-tech firms entering mainland China consider merger and acquisitions to be the first priority, and followed by strategic alliances. This research shows that if the stock share holding is unlimited, Taiwanese bio-tech firms prefer to select a high stock share holding investing mode. (3) In various investment modes, the aspects of "Capital and Risk" and "Technology Ability" have the most consistent effect on entry mode selection.

1. Introduction

Zadeh (1965) introduced fuzzy set theory to illustrate the fuzzy phenomena occurring in human activities. Human behaviors and conceptual languages can be converted into fuzzy numbers using the uncertain elements of fuzzy set membership. Van Laarhoven and Pedrycz (1983) showed that these fuzzy numbers can be calculated and ranked. In addition, Mikhailov and Singh (1999) performed a comparative study on traditional crisp values and fuzzy intervals, and found that fuzzy measures perform better than crisp values. In complex multi-criteria scenarios, an expert decision-maker often has too much information to analyze and evaluate, and thus cannot easily make consistent decisions. Chen, Lin, Wang, and Chang (2006) used four different types of membership functions to represent the weighted linguistic variables of the different professional abilities of expert decision-makers. They also measured these linguistic variables using three distinct types of membership functions, and quantified linguistic variables. Chen and Klein (1997) introduced the defuzzying method to calculate crisp values by the relationship between the referential rectangle and triangle fuzzy numbers.

Fuzzy measures view the performance of criteria as candidate fuzzy sets, and can be used to determine the degree to which are involved in the performance of criteria in fuzzy set membership. The value of the fuzzy measure includes the connotative weights of criteria performance. In other words, the fuzzy measure has an dependent interaction effect on the criteria under consideration. Eliminating the assumption that the probability of all sets is 1, the fuzzy measure transfers the additive probability into non-additive fuzzy measure. The λ-fuzzy measure, called the Sugeno measure (Sugeno, 1974), can fulfill the λ additive axiom, making it easier to define the fuzzy measure. The constrained parameter, λ, of the λ-fuzzy measure indicates additivity among its elements. Compared with other fuzzy measures, the λ-fuzzy measure is easily and extensively applied to determine the value of fuzzy measure (Chen & Wang, 2001; Lee & Leekwang, 1995). When an expert decision-maker evaluates the alternatives, more criteria create more sophisticated calculations of the λ-fuzzy measure. Lee and Leekwang (1995) employed a genetic algorithm (GA) to calculate the value of the λ-fuzzy measure incomplete information. Chou (2007) provided a GA computer program to obtain the optimal value of λ using Matlab R2007a software. Takahagi (2000) normalized the λ-fuzzy measure to easily explain the value of the fuzzy measure.

In 1970, Thomas L. Saaty developed an analytic hierarchy process (AHP) decision model that is suitable to exercise the multi-criteria group decision of subjective judgment (Lai, Wong, & Cheung, 2002). Even through Saaty's AHP has many defects in reality, it can decomposes complex problems using hierarchical structures, and ultimately benefit the construction of the decision model. Chen (2001) employed the fuzzy integral to amend the disadvantages

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of traditional AHP. The fuzzy integral successfully accounts for the process of human subjective judgment and more accurately reflects real situations. Moreover, the revised fuzzy integral considers the relationships between criteria at any given time. By calculating the weights of AHP through manipulated or transited effects among criteria, the revised fuzzy integral can accurately reflect real situations. Comment integrals include the Sugeno Integral, Weber Integral, and Choquet Integral. Among these integrals, the Choquet Integral is a non-additive utility function that is suitable to exercise multi-criteria decision problems. Therefore, this study adopts Choquet's fuzzy integral to calculate the overall performance of each alternative. Furthermore, Takahagi (2005) designed a Choquet Integral program of λ fuzzy measure to calculate the value of the Choquet Integral more easily.

From the viewpoints of organizational management and operation, Root (1994) separated the foreign investment (FI) entry modes into: (1) exports, including indirect exports, direct exports and others; (2) contract cooperation, including licensing, franchising, technical agreements, service contracts, management contracts, turnkey, contract/manufacture, counter trade arrangements, and others; and (3) local investment, including unique investment – investing in a new establishment, unique investment – acquisition, joint venture – creating a new establishment, joint venture – purchasing the stocks of existing company, and others. Pan and Tse (2000) differentiated the level of entry modes between equity and non-equity relationships. Furthermore, Chen and Lou (2004) illustrated the modes of strategic alliance using the exchange types of the relationship between the degree of integration and control. Yoshino and Rangan (1995) divided strategic alliances into contract agreements and equity agreements based on the types of equity. Finally, Narula and Hagedoorn (1999) differentiated between the modes of technology transfer for equity and non-equity agreements.

To summarize the categories of entry modes in the literature described above, this study simplifies these research processes and considers current bio-tech developing situations. The FI entry modes of the bio-tech (or pharmacy) industry indicated by Chen and Lou (2004) not only effectively measure different assessment criteria, but can also reduce the complexity of assessment factors in various entry modes and their alternatives.

(1) Considering the entry mode survey questionnaires release and the respondent willingness to reply, Chen and Lou (2004) developed the following entry modes: (1) joint venture, (2) minority holding strategic alliance, (3) joint R&D, (4) joint production, (5) joint marketing and promotion, (6) enhancing the partner relationship with a provider, (7) R&D contract, and (8) licensing agreement. This study simplifies and rearranges theses entry modes into the following four categories: "Joint Venture," "Strategic Alliance," "Merger and Acquisition," and "Cooperation Contract."

(2) The research subjects in this study are Taiwanese bio-tech firm experts who are willing to invest in, or are currently investing in, Mainland China.

Facing growing international competition, many Taiwanese bio-tech firms have begun to invest heavily in R&D to develop innovative products or processes. Bio-tech firms in particular face the challenge of high barriers to entry, long-development time, and a high failure rate. Most of bio-tech firms are small and medium enterprises whose main revenues come from manufacturing and selling products, and they often lack investment capital. The models in Table A1 in Appendix A show that cooperation among universities, research institutes, bio-tech firms, and other related industrial companies is becoming one of the major strategies in bio-tech business operations.

According to previous studies (Dunning, 1988; Kim & Hwang, 1992), the aspects of strategic motivation, knowledge, and techniques (Agarwal & Ramaswami, 1992; Cho & Yu, 2000; Pearce & Papanastassiou, 1996; Shan & Song, 1997), location-specific advantage (Agarwal & Ramaswami, 1992; Allansdottir et al., 2002; Brouthers, 2002; Cho & Yu, 2000; Dalton & Serapio, 1999; Deeds, DeCarolis, & Coombs, 2000; Isbasoiu, 2006; Pearce & Papanastassiou, 1996; Richards & DeCarolis, 2003; Robertson & Gatignon, 1998; Shan & Song, 1997; Shih, 2006; Yiu & Makino, 2002), ownership-specific advantages (Agarwal & Ramaswami, 1992; Coombs, Mudambi, & Deeds, 2006; Deeds & Hill, 1996; Ekeledo & Sivakumar, 2004; Shih, 2006), internalization advantage (Woiceshyn & Hartel, 1996), and their influence on FI are the primary factors affecting FI for bio-tech firms.

Other research on the bio-tech industry is directed at internationalized joint ventures. Richards and DeCarolis (2003) found that similar and complementary product lines from the cooperative enterprises, culture distances, country risks, and prior cooperative experiences all result in different forms of joint-ventures in R&D activities. Vanderbyl and Kobelak (2007) conducted a study on the key success factors of 247 Canadian bio-tech firms. Their study demonstrates that bio-tech firms rely more on external resources in the early stages, and modern bio-tech firms usually acquire more venture capital. No matter what stage bio-tech firms are in, the key success factors is the accumulation of intellectual capital. As a result, the number of patents a bio-tech firm possesses can measure its technical capital (Deeds, DeCarolis, & Coombs, 1997; Greetham, 1998). Shan and Song (1997) assumed that the key success factors for bio-tech firms lied in the acquisition of venture capital (VC), business partners, success of initial public offering (IPO), accomplishment of clinical trials, electable products, or technology commercialization. Hence, sufficient long-term capital is an important factor in the survival of bio-tech firms. Table A2 in Appendix B lists the influential factors of foreign investment and their related studies.

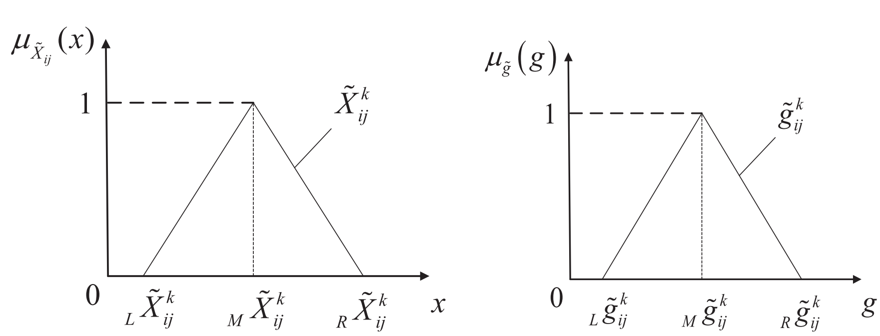

Fig. 1. Illustration of fuzzy triangular fuzzy numbers for Linguistic assessment variable, $\tilde{X}_{ij}^k$, and its fuzzy weighted variable, $\tilde{g}_{ij}^k$.