Chaos, Solitons and Fractals 89 (2016) 284–289

Contents lists available at ScienceDirect

Chaos, Solitons and Fractals

Nonlinear Science, and Nonequilibrium and Complex Phenomena

journal homepage: www.elsevier.com/locate/chaos

Research on the robust optimization of the enterprise's decision on the investment to the collaborative innovation: Under the risk constraints

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ARTICLE INFO

Article history:
Available online 28 December 2015

Keywords:
Risk constraints
Collaborative innovation
Robust optimization
Game

ABSTRACT

The robust optimization model is applied to analyze the enterprise's decision of the investment portfolio for the collaborative innovation under the risk constraints. Through the mathematical model deduction and the simulation analysis, the research result shows that the enterprise's investment to the collaborative innovation has relatively obvious robust effect. As for the collaborative innovation, the return from the investment coexists with the risk of it. Under the risk constraints, the robust optimization method could solve the minimum risk as well as the proportion of each investment scheme in the portfolio on the condition of different target returns from the investment. On the basis of the result, the enterprise could balance between the investment return and risk and make optimal decision on the investment scheme.

1. Introduction

Currently, the "innovation-driven development" has become a significant strategy for China to accelerate the transformation of the economic development pattern. According to the report to the 18th National Congress of the Communist Party of China and 2015 Chinese government work report, China will "place greater emphasis on making innovation through collaboration, and establish a system of technological innovation in which enterprises play the leading role, the market points the way, and enterprises, universities as well as research institutes work together". These statements indicate that the collaborative innovation is the key way for the implementation of innovation-driven development strategy. Researchers in China have different opinions on the collaborative innovation in China. Chen and Yang (2012) believed that the core of the collaborative innovation is increasing the human knowledge, and the collaborative innovation is essentially an organizational model for enterprises, government, knowledge production sectors (such as universities, research institutions), intermediaries and customers collaborate extensively for major S&T innovation in quite a wide range of fields [1]. Hong (2013) argued that the China's version collaborative innovation is not a general sense of collaborative innovation between peers or members of a supply chain, neither be a simple inheritance of the university-industry cooperation. Instead, it is a system in which universities, enterprises, S&T intermediaries and financing institutions conduct joint operations [2]. So, Zeng et al. (2013) concluded that the collaborative innovation should be an ecosystem in which the participants integrate with each other, create new value chains and then generate an open network of collaboration [3]. The participants and their resources constitute a structure of mutualistic symbiosis in this ecosystem, and the ecosystem would optimize for the best of all the participants through its evolution. During the process of the collaborative innovation, how the enterprises achieves the goal of benefit maximization through knowledge transfer and S&T achievements transformation between each other is the key to the continuous development of the collaborative innovation.

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http://dx.doi.org/10.1016/j.chaos.2015.11.021
0960-0779/

But in fact, the collaborative innovation is faced by huge risks and challenges, especially the performance of collaborative innovation would be directly influenced by the participants' game behaviors of. In order to analyze the participants' decision making behaviors in the collaborative innovation, many researchers construct the game analysis model. Zhou et al. (2008) developed a dynamic model of cooperation R&D network-based game and analyze firms' R&D investment decisions by integrating independent research and cooperative research. The research reveals that a firm's investment in the independent projects as well as in each of the joint projects increases with collaborative degree and exogenous coefficient, and decreases with collaborative size [4]. Qi et al. (2008) presented a game model among the government, enterprises, as well as universities and institutions [5]. Xu et al. (2014) analyzed the collaborative relationship between enterprises based on the "prisoner dilemma" model, and pointed out how enterprises maximally enhance the performance of the collaborative innovation. Then, they discussed how the enterprises and government optimize their own benefit through evolutionary game in the process of collaboration. Based on the game rules concluded by their research, the measures to realize the collaborative innovation has been proposed [6]. Liu et al. (2015) constructed a profit distribution model of university-industry collaborative innovation value chain based on double efforts by utilizing the thought and methodology of the game theory and conflict economics. Then, the optimization model was used to solve the optimal effort degree and the optimal cooperation degree with non-coordination and coordination [7]. Huang et al. (2015) proposed a game model of collaborative innovation with venture capital funding. Their research found that the fund should give the supplier the investment later during the period of innovation, while the innovation supplier invests its own capital at earlier stages, in order to stimulate it to raise innovation commitment [8]. Arsenyan et al. (2015) proposed a model integrating trust, coordination, co-learning, and co-innovation dimensions of collaborative research between firms, and the analysis investigated the effect of various parameters on the collaboration formation as well as the revenue sharing under various scenarios with the Nash Bargaining theory, and finally summarized the optimum strategies for each scenario [9]. To sum up, most researches have considered the profit distribution problem between participants of the collaborative innovation in stable environments few scholars conduct the research about the collaborative innovation in dynamic environments. However, the risk factors in dynamic environments should be paid more attention by the participants in the collaboration.

In dynamic environments, enterprises have to take the external environments into account when they make the investment decision, and especially the competing environment (D'Aveni, 1994; Porter, 1980) [10,11]. Drazin and Van de (1985) believe that the goal of survival and development make enterprises to keep the internal decision-making matched with external environments [12]. As for the collaborative innovation, the uncertainty of external environments has remarkable influences to the innovation performance, so the R&D investment decision of each enterprise should match the dynamic environments (Choi, 1993; Katsoulacos and Ulph, 1998; Narula, 2002; Silipo and Weiss, 2005) [13–16]. Some literatures constructed the analytical framework for Synergetic Innovation (SI) based on Synergetics to characteristics and evolution mechanism of SI of emerging industries showing that SI of emerging industries was a complex process of the interaction between the internal driving of innovation subject of industrial innovation system and external environment and SI is in the dynamic process of evolution with the development of the industries, which was from breeding phase to germination phase and growth phase (Chen and Sui, 2015) [17]. The current researches about investment decision of collaborative innovation have not considered the risks and benefits of it, and the uncertainty of dynamic environments has not been analyzed. Therefore, in this paper we study the enterprises' decision on the investment to collaborative innovation under the risk constraints in the uncertainty environment. An analysis is conducted with the robust optimization model to investigate the impact of dynamic environments, solve the minimal risk of the portfolio and provide an investment plan for the collaborative innovation.

2. Collaborative innovation decision analyses under the dynamic environment

According to Goyal et al. (2003) [18], enterprise collaborative innovation activities generally include three stages: (1) formation of collaborative innovation network; (2) every enterprise allocates resource to the independent and collaborative innovation activities and these decisions decide the effective cost of production; (3) the enterprises take part in the Cuno competition in product market. There are different decision problem at different stage for enterprise. Enterprises need to decide whether to participate in collaborative innovation firstly. Then, if they take part in collaborative, they should make investment decision. At last, according to the result of innovation, enterprises would consider the decision of competition. Based on above, we can build the model as follows.

2.1. Collaborative innovation decision analyses

Suppose $N = \{1 \ldots n\}(n \geq 2)$ is a set of enterprises on the market. The collaborative networks formed in the first stage can be expressed by g. If $i \in g$, it means that the company i participates in the collaborative network. $N_i(g)$ denotes the enterprises set which has collaborative relationship with enterprise i in network g. $n_i(g) = |N_i(g)|$ is the number of collaborative enterprises with enterprise i in network g. In this paper, We define it as the collaborative innovation scale of enterprise, denoted by $k \in \{1, 2, \ldots, n\}$, $k = 1$ means completely independent innovation and $k > 1$ means the formation of collaborative innovation network.

Suppose g is the network generated in the first stage, and x_{ig} is the collaborative innovation investment of enterprise i in g. To maintain the core competition ability, enterprise invests x_{ii} for improving independent innovation. $x = (x_{ig}, x_{ii})$ is the strategic choice in the game of enterprise i and $x = (x_i)_{i \in N}$ represents the strategy portfolio in the game.