Technological Forecasting & Social Change 77 (2010) 857–869

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Modeling technological innovation risks of an entrepreneurial team using system dynamics: An agent-based perspective

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ARTICLE INFO

Keywords:
Risk-based decision-making (RDM)
Entrepreneurial team
Technological innovation risk
Agent-based modeling
System dynamics

ABSTRACT

Continuous technological innovation has been playing a vital role in ensuring the survival and development of an enterprise in today's economy. This paper studies the problem of technological innovation risk-based decision-making from an entrepreneurial team point of view. We identify the differences between this team decision-making and a traditional individual decision-making problem, where decisions are mainly affected by the decision-maker's risk and value perceptions, and risk preferences. We create a modeling framework for such a new problem, and use system dynamics theory to model it from the agent-based modeling perspective. The proposed approach is validated by a case study of the technological innovation risk decision-making in a Chinese automobile company.

1. Introduction

Since the financial crisis, the encouragement of business startups has become the consensus of all walks of life to promote employment; many major cities in China also have proposed a "full business" strategy, and launched a large number of business support measures under the direction of macroeconomic policy. Entrepreneurial success mainly depends on three factors: venture projects, business operations and entrepreneurs. Among these three factors, entrepreneurial activity is the core of success. Since 1977, Cooper and Bruno [1], Thurston [2], Feeser and Willard [3], Doutriaux [4], and Chandler and Hanks [5] have suggested that venture performance created by an entrepreneurial team is often superior to one created by a single entrepreneur. Lechler [6] also believes that the average success rate of new enterprises created by teams is higher than that of new enterprises created by individual entrepreneurs. The entrepreneurial environment has become increasingly complicated, but well-designed and efficient entrepreneurial teams can quickly analyze, evaluate and predict changes from external environment. At the same time, from the perspective of entrepreneurial opportunities, entrepreneurial teams have greater capacity for opportunity identification, development and utilization.

In today's economy with ever-changing technology, continuous technological innovation has been playing a vital role in ensuring the survival and development of an enterprise [7,8]. Technological innovation decisions have become a very important decision problem that cannot be ignored in the entrepreneurial team decision-making. In this work, we study the problem of technological innovation risk decision-making in an entrepreneurial team for typical enterprises. Such a problem has two main differences from traditional technological innovation risk decision-making (DM): first, the difference between startups and traditional enterprises; and second, the difference between entrepreneurial team decisions and individual decisions. On the one hand, compared to a general enterprise, technological innovation in entrepreneurial enterprises has higher motivation of

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doi:10.1016/j.techfore.2010.01.015

technological innovation and lower innovation capability. This suggests an entrepreneurial team may prefer to be risk-seeking in startups in order to gain technological innovation in the organization. On the other hand, decision-making in an entrepreneurial team is different from how individuals deal with risks. Entrepreneurial team risk decision-making typically focuses on what action a group should take. Individual decision-making is mainly affected by individual decision-maker's subjective factors, including decision-maker's risk and value perceptions, risk preferences, etc. However, the entrepreneurial team includes a number of DM individuals, where the impacts of a single DM's subjective factors have been significantly reduced. Instead, the composition of decision-makers' opinions, the mutual relations among policy-makers and a team's DM system have a greater impact on decision outcomes. This study describes the general theory of technological innovation risk decision-making in an entrepreneurial team.

Both SDM and ABM have been used in the field of technological forecasting modeling and risk analysis [9–11]. We model this DM problem using a system dynamics model (SDM) from the agent-based modeling (ABM) perspective. SDM uses feedback loops and stocks and flows to model the behavior of complex systems over time and deals with internal feedback loops and time delays that affect the behavior of the entire system. SDM is a good tool for modeling aspects of organizational behavior due to its significant capabilities for modeling human behavior and DM processes [12]. The strength of System Dynamics lies in its ability to account for non-linearity in dynamics, feedback, and time delays.

ABM has been treated as a powerful tool for modeling complex adaptive systems with multiple entities reacting to the pattern these entities create together. Agents in ABM represent autonomous DM entities. ABMs have been employed since the mid-1990s to solve a variety of business and technology problems. Examples of applications include supply chain optimization and logistics, modeling of consumer behavior, social network effects, workforce management, and portfolio management. Both ABM and SDM have a high potential for supporting and complementing each other [12].

To make group decisions in an entrepreneurial team, lots of heterogeneous participating entities can be involved; they not only interact dynamically with each other, but also adapt or react to patterns generated or forecasted. Traditional optimization approaches, equilibrium analysis, or other analytical techniques usually fail to handle these complexities. To model entrepreneurial team risk features and various team interaction and adaptive behaviors, we treat the node representing a single executive officer in the system dynamics model as an Agent. Agents modeling a number of nodes will be used to simulate the interdependent DM reactions among the business executives. Group DM solutions can be obtained by running the system dynamics models for the whole entrepreneurial team.

The proposed approach is validated by a case study of technological innovation risk decision-making in a Chinese automobile company — the Automobile Technology Development Ltd. of Wuhan Genpo. The agent simulation and analysis were performed by an entrepreneurial team of three senior executives. Results show that the agent-based technological innovation risk DM model in entrepreneurial team is appropriate for start-up enterprises. In addition, SDM was found useful in providing practical guidance to risk-based decision-making.

Section 1 has presented literature review. Section 2 discusses risk-based decision-making (RDM) in the context of a technological innovation project. Section 3 presents models and analysis. Sections 4 and 5 present a case study validating the proposed models using system dynamics, and Section 6 concludes the paper.

2. Individual RDM of a technological innovation project

Technological innovation activity contains uncertain factors in each stage and component, giving it high-risk. The probability of a successful technological innovation is often less than the probability of failure. Technological innovation risk is mainly due to the uncertainties of technology, market, innovation benefits and institutional environment. Technological innovation projects involve decision uncertainty, complexity, multiple objectives, and dynamic interactions. We present such an individual RDM problem in the following modeling framework, which also serves as the basis for the technological innovation RDM in an entrepreneurial team.

2.1. Modeling

Suppose an entrepreneurial team member intends to make decisions of a technological innovation project, in order to decide on 1) whether to carry out the project, and 2) if adopted, how much to invest. The project can be either adopted at a high level with large investment or at a normal level with small investment. Human risk behavior has been researched as individual cognitive process where individuals collect and treat information to form their actions and decisions [13,18]. Psychological-based researchers have paid a great deal of attentions to the role of human preference expands the interest of risk management beyond objective data concerning probabilities to the more complex judgmental forum requiring subjectivity [19–21].

In such a technological innovation project, there are three major factors affecting the individual's RDM result: risk perception, value perception and risk preference. These factors can be seen as three input variables in technological innovation risk decision-making. Risk perception and value perception have an impact on individual decision-making through the internalization of the input risk and value information of the decision-making object perceived by the decision-maker. Risk preference is an inherent property, which directly influences the decision-making outcome by influencing the decision-maker. For such a decision-making problem, we also assume there are three possible outcomes corresponding to the three input factors: reject, agree to proceed and take the radical scheme with large investment and agree to proceed but take the conservative scheme with small investment. As a result, these three factors, three possible outcomes and the decision-maker constitute an individual RDM system together, which is depicted in Fig. 1.