



The impact of risk attitude in new product development under dual information asymmetry



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ARTICLE INFO

Article history:

Received 24 February 2014
Received in revised form 21 June 2014
Accepted 24 July 2014
Available online 7 August 2014

Keywords:

Uncertainty theory
New product development
Information asymmetry
Wage contract

ABSTRACT

This paper investigates the impact of risk attitude on incentives and performances in a two-stage (research stage and development stage) new product development setting with one senior executive (she) and one project manager (he). The senior executive offers a wage contract to the project manager in the presence of dual information asymmetry including his unknown idea value of a new product in early research stage and unobservable effort to convert the idea into a product in later development stage. Due to the variability of technology and market, the subjective assessments about the idea value and the revenue generated by the product are characterized as uncertain variables. Within the framework of uncertainty theory, we first present four classes of uncertain principal agent models, and then derive their respective optimal wage contract mechanisms. We find that the structures of the senior executive's optimal mechanisms depend on the project manager's risk attitude. If the project manager becomes more conservative, the senior executive should set a low incentive term to avert risk. Otherwise, she should do the opposite. Moreover, we identify two values: the information value of the idea—how much the senior executive is willing to pay to acquire information regarding the project manager's idea value, and the information value of the effort—how much the senior executive ensures to win when she can contract on the project manager's effort. Our results show that acquiring the project manager's idea information yields the highest potential when the project manager is aggressive, but in the case of contracting on his effort, the opposite appears to be true. The results also indicate that acquiring more information on an aggressive project manager's idea always has higher impact on the senior executive's profits than contracting on his effort. We also provide several interesting managerial insights in new product development through our analytical and simulation results.

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1. Introduction

New product development (NPD) has attracted an ever growing attention in recent years both from academic area and industry. Two crucial factors seem to make it necessary for many firms to develop new products: the idea value of the new product and the effort provided by their project managers to develop the product. For instance, Apple elicits the ideas related to “handheld and tablet devices” from the project managers and ultimately develops iPhone and iPad products which capture enormous market. Google effectively uses incentives to ensure that the project managers invest development effort in NPD for the Google Chrome web-browser. As a result, the firms can better operate the NPD projects by investing care in these two factors.

In this paper, we investigate how the risk attitude impacts the optimal wage contract mechanisms, the information value of the idea and that of the effort, as well as what types of information value would be greater. This paper aims to answer these questions in a two-stage NPD setting, where a senior executive engages a project manager to develop a new product. Specifically, the project manager is responsible for executing two stages: a research stage and a development stage. In the research stage, he discovers an idea and subsequently exerts effort to transform the idea into a product in the development stage. It is likely that the existence of dual information asymmetry between the senior executive and the project manager roots from the fact that the idea value of the new product in early research stage is unknown to the senior executive and the project manager may exert unobservable effort in later development stage. The senior executive offers a wage contract to ensure that the project manager reveals true idea information and invests adequate effort to create value. In addition, due to the variability of technology and market associated with the new

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product, the idea value of such new product and the corresponding revenue are assumed to be uncertain variables. Within the framework of uncertainty theory, we first present four kinds of uncertain principal agent models, and then derive the closed form expressions for the optimal wage contracts. By the obtained results, we establish the following main findings.

- We characterize the optimal incentive wage contracts offered by the senior executive under four different scenarios. The finding is that the structures of the senior executive's optimal mechanisms depend on the project manager's risk attitude. If the project manager becomes more conservative, the senior executive should set a low incentive term to avert the risk. Otherwise, she should do the opposite.
- We find that the information value of the idea depends on the project manager's risk attitude. In other words, the more aggressive the project manager is, the greater the information value of the idea is. Furthermore, the information value of the idea is greater for the senior executive when she cannot contract on the project manager's effort.
- We also come to the conclusion that the information value of the effort relies on the project manager's risk attitude. Unlike the information value of the idea, the more conservative the project manager is, the greater the information value of the effort is. In contrast to intuition, we find that the information value of the effort for the senior executive is not necessarily larger under symmetric information.
- We further compare the information value of the idea with that of the effort. The finding is that the former is greater than the latter when the senior executive engages an aggressive project manager. That is, from the senior executive's perspective, having more information on an aggressive project manager's idea always has higher impact on profits than contracting on his effort.

The paper is organized as follows. In Section 2, we briefly review related literature. The model is described in Section 3. In Section 4, we present the optimal wage contracts under symmetric idea information. The optimal wage contracts under asymmetric idea information are presented in Section 5. Section 6 explores the information value of the idea and that of the effort, as well as their interaction. A simulation study is demonstrated in Section 7. Section 8 summarizes our research contributions and outlines directions for future research. Preliminaries on uncertainty theory and proofs of all propositions and lemmas are relegated to the appendix for clarity of presentation.

2. Literature review

This paper draws on two streams of literature: the operations management literature on NPD and the economics literature on principal agent problems.

NPD has attracted interests from both researchers and practitioners of operations management. Various operational tools that deal with NPD have been studied: the nonstationary Markov decision process (Dragut, 2006), the implementation of project strategy (Yang, 2012) and the multi-objective team formation optimization (Zhang & Zhang, 2013). For more detailed information about NPD, see Krishnan and Ulrich (2001) and Shum and Lin (2007). Recently, a number of papers study issues of incentives for NPD. For example, Chao, Kavadias, and Gaimon (2009) studied how funding authority and incentives affect a central manager's allocation of resources between existing product improvement and NPD, which are managed independently by two decision makers. Mihm (2010) considered an internal cost-gaming issue in a NPD project and showed

how incentive schemes, such as profit-sharing contracts and component-level target costing, could provide incentives for engineers to improve cost compliance of the project. The above works failed to consider two-stage NPD except that Chao, Lichtendahl, and Grushka-Cockayne (2013) developed a principal-agent model to study how the firm should design incentive mechanisms for the project manager in two-stage NPD with a stage-gate process. In contrast to Chao et al. (2013), we incorporate the project manager's risk attitude into an NPD problem and investigate the impact of risk attitude on incentives and performances in such a setting.

The economics literature on principal agent problems is vast (see Che & Yoo, 2001; Demski & Sappington, 1984; Holmstrom, 1982; Itoh, 1991; McAfee & McMillan, 1991; Mookherjee, 1984). These papers characterized the subjective assessments about asymmetric information and uncertainty as random variables based on probability theory. However, probability theory is no longer applicable in the NPD setting, because the probability distribution cannot be estimated from the frequency due to the lack of it. In contrast, we assume the assessment about asymmetric idea information and the revenue of the new product to be uncertain variables based on uncertainty theory founded by Liu (2007) which has been widely applied to various fields (see Chen, 2012; Gao, Gao, & Relascu, 2010; Yao, 2012; Qin & Kar, 2013; Sheng, Zhu, & Hamalainen, 2013). It has been proved appropriate to depict subjective assessment and model human uncertainty.

Recent years, several scholars have used uncertainty theory to develop the principal agent theory. For example, Mu, Lan, and Tang (2013) incorporated adverse selection with no moral hazard in an uncertain contract model for the rural migrant worker's employment problem to maximize the enterprise's expected utility under the asymmetric home-income information of the rural migrant worker. Wang, Tang, and Zhao (2013) presented an uncertain price discrimination model in labor market to maximize the employer's expected welfare, in which there is adverse selection but no moral hazard. Wu, Zhao, and Tang (2013) discussed a moral hazard problem with multi-dimensional incomplete information between a principal and an agent based on the critical value criterion, but their model does not consider adverse selection. Our paper differs from these three works in two respects. First, we consider both the expected value criterion and the critical value criterion in a two-stage NPD setting. Second, we investigate the impact of risk attitude in an uncertain principal agent problem with adverse selection and moral hazard.

3. The model framework for NPD

Consider a senior executive contracting with a project manager to develop a new product. The project manager is responsible for executing two stages: a research stage and a development stage. In the research stage, the project manager discovers an idea and subsequently exerts effort to transform the idea into a product in the development stage. There exists information asymmetry including the unknown idea value in early research stage and the unobservable effort in later development stage. We model the senior executive as the principal and the project manager as the agent to investigate how risk attitude impacts on incentives and performances in this NPD setting. More specifically, the problem confronted by the senior executive is thus a mixture of adverse selection and moral hazard, where adverse selection exists in the early research stage and moral hazard exists in the later development stage.

3.1. Notations and assumptions

In the research stage, the project manager privately learns the idea value of the new product, which is not relayed to the senior

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