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Innovative Applications of O.R.

Step by step. The benefits of stage-based R&D licensing contracts

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ABSTRACT

We examine how a licensor can optimally design licensing contracts for multi-phase R&D projects when he does not know the licensee's project valuation, leading to adverse selection, and cannot enforce the licensee's effort level, resulting in moral hazard. We focus on the effect of the phased nature typical of such projects, and compare single-phase and multi-phase contracts. We determine the optimal values for the upfront payment, milestone payments and royalties, and the optimal timing for outlicensing. Including multiple milestones and accompanying payments can be an effective way of discriminating between licensees holding different valuations, without having to manipulate the royalty rate, which induces licensees to invest less, resulting in lower project values and socially suboptimal solutions. Interestingly, we also find that multiple milestone payments are beneficial even when the licensor is risk-averse, contrary to standard contract theory results, which recommend that only an upfront payment should be used. In terms of licensing timing, we show that the optimal time depends on the licensor's risk aversion, the characteristics of the licensee and the project value.

1. Introduction

R&D projects typically consist of a series of phases, in the course of which technology and market risk is gradually resolved. A typical example can be found in the pharmaceutical industry, where regulatory requirements enforce a strict procedure of sequential phases with specific milestones at which the project is assessed. A similar pattern can be found in most new product development environments in high-technology industries. This phased nature of R&D projects is also mirrored in the contracts that govern licensing deals. In this paper, we examine how a licensor should design and structure such licensing contracts in the presence of information asymmetries to extract the highest possible value from the deal. We focus on a commonly used contract structure containing an upfront payment, lump sum payments at the successful completion of milestones, and royalties on the product's sales. This work extends the analysis presented in a paper by Crama et al. (2008) that focused exclusively on single-phase projects. In this paper, we demonstrate the importance of explicitly acknowledging the phased nature of R&D projects when designing licensing contracts, and present insights into how to structure such contracts. We examine at which stage it is optimal to license out a project, and whether the contract should contain an upfront payment, one or more milestone payments and/or royalties. We also derive insights into the impact of the licensor's risk aversion and the presence of moral hazard and adverse selection on these recommendations.

Our work with Phytopharm, a biotechnology company based in Cambridgeshire, England, introduced us the problems of R&D project valuation and licensing. Phytopharm had discovered appetite suppressant properties of a natural compound, and was looking for a partner to complete the development of the product and launch it in the meal replacement market. During the negotiations, various aspects of the project were scrutinized by their potential partners, including the structure of the project, the probability of technical success (PTS) of the project phases, development costs and sales forecasts. A major issue, however, was disagreement on the PTS of the project and its different phases, how the licensing contract should be structured, and which payments should be included at which phases in the contract. To support these negotiations, we developed a model to help value the project and different possible licensing deals (Crama et al., 2007). In the end, Phytopharm secured a deal with Unilever, which bought the exclusive rights to include the compound in its existing range of weight loss products, in exchange for an upfront payment, a series of milestone payments and royalties on the sales revenue of the product range.

Based on our experiences with Phytopharm, we investigate two sources of information asymmetries when designing licensing contracts, resulting in adverse selection and moral hazard. First,

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we examine the consequences of a licensor and licensee disagreeing on the PTS of a particular project and each of its phases, and thus also the likelihood that the product will reach the market. In fact, the licensor may not even know the licensee's PTS estimate for each of the project phases. For instance, when a biotech company is negotiating a licensing deal with a large pharmaceutical company, the latter can use its in-house experts to generate its own PTS estimates, adjusting them to the specificities of the project and its own expertise in the field. Macho-Stadler et al. (1996) mention that "the licensee is in some cases better acquainted with [...] the application of the innovation to his productive process". Conversely, a non-pharmaceutical licensee may have more limited knowledge about the project and the technology, and might thus make more conservative estimates than those presented by the biotechnology company. The PTS estimates directly affect the value of the project, which may expose the licensor to adverse selection: the licensee has an incentive to misrepresent her valuation and understate her estimates of the project's PTS to reduce the perceived project value (see also Du et al., 2006). Second, because the product sales and the licensor's royalty revenues depend on the licensee's development and marketing effort, a licensee might not invest enough in these activities to generate the best possible outcome for the licensor. We examine the impact of this type of moral hazard on the optimal contract design for the licensor.

We tackle these issues from the perspective of the licensor, who acts as the principal in the principal-agent models developed to optimize the design of the licensing contract. We have chosen the licensor as the principal because licensors in the pharmaceutical industry enjoy increasing bargaining power. Indeed, the biotech company offers a unique product in a market characterized by soaring demand for in-licensing from large pharmaceutical companies and a high level of maturity of the biotech industry. Biotech companies' rising market power is reflected in the increased value of recent deals (Financial Times, 2006, 12 January 2006), which has lead to the observation that the pharmaceutical licensing market has "become a sellers' market" in which the power balance is shifting to the benefit of the biotech companies. As the licensor suffers from incomplete information about the licensee and does not know the licensee's valuation of the project, determined by her PTS estimates, he formulates this as a screening problem.

This paper makes three contributions to the literature. First, we investigate whether the results and managerial implications of adverse selection and moral hazard for the licensor's optimal contract design presented by Crama et al. (2008) for a single-phase project can be extended to explicitly incorporate the phased nature of R&D projects. That phased nature creates multidimensional licensees types, i.e., the licensee is characterized by several different PTS estimates, one per phase, each of which affects her valuation of the project. To preserve analytical tractability, we restrict our analysis to two phases, as this is sufficient to capture the complexities and effects of the multi-stage nature of licensing contracts in practice, and the multidimensional nature of the problem. We examine whether the results and insights from the single-phase case extend to the multi-phase case, and find that this only happens under certain conditions, which define the additional complexity introduced by the multidimensional nature of phased projects. Second, we illustrate the impact on the contract structure when these conditions do not hold. We find that the optimal contract may include more than one milestone payment and distort the timing of those payments for licensees holding both high and low project valuations, contrary to the single-stage setting in which the contracts of high-value licensees are never distorted, i.e., their contracts are designed to maximize total value. Third, using a multi-phased setting allows us to examine in detail the role of royalties. We find that royalties should only be used for licensees having a low incentive to invest in the project, which also implies that royalties use the licensees' difference in their incentives to invest to discriminate. Finally, we analyze in which phase to out-license a project and we examine which elements have an effect on this, including the licensee's characteristics and the licensor's degree of risk aversion.

In the next section, we present a literature review on multidimensional adverse selection, one of the key issues when designing multi-phase contracts. Section 3 describes the licensor's problem in detail and introduces the relevant concepts. Section 4 presents optimal contract structures for licensing multi-phase R&D projects under different assumptions of information asymmetry. Section 5 examines the optimal timing of the licensor's licensing decision. Section 6 presents a number of managerial insights derived from our analysis, for both the licensor and the licensee. We conclude in Section 7 with some avenues for future research.

2. Literature review

The literature in economics and management has long recognized the phased nature of R&D projects. Quinn and Mueller (1963) present a generic R&D project structure based on their observations of practice. They recommend that management prepare a decision plan determining the information needed to decide on the further life of the project at the end of each phase. Sturmey (1966) makes an argument for defining phases in an R&D project as points at which it may be "cheaper to stop than to go ahead". Kelm et al. (1995) discuss papers advocating the phased representation of projects. Huchzermeier and Loch (2001) show how the phased nature of R&D projects generates value by creating opportunities for flexibility in the project execution, which corresponds to a real option. We contribute to this stream of research by investigating the impact of phasing an R&D project on the licensor's revenue stream from licensing.

There is a large body of literature on contracting with information asymmetry of which Crama et al. (2008) provide an extensive review. Papers studying the contract structure for R&D or innovation licensing in particular typically include a combination of upfront payment, milestone payments and royalties, and study the impact of those contract elements on the value captured by the innovator (e.g. Decheneaux et al., 2009; Erat et al., 2007), the execution of the project by the licensee (e.g., Aghion and Tirole, 1994; Decheneaux et al., 2009) or the innovator (Decheneaux et al., 2011), or the incentive to invest in research under competition (Kulatilaka and Lin, 2006). Xiao and Xu (2009) look at a multi-stage R&D setting with informational asymmetry about the innovator's capability. They allow renegotiation after additional information about the product becomes available. The renegotiation centers around the level of royalties, and the conditions under which those royalties increase (decrease) are determined based on the relative technical and market uncertainty. Bhaskaran and Krishnan (2009) choose to go beyond contracts that share revenue to also allow the sharing of development cost. They model the shared decision-making problem and look at how uncertainty and differences in capabilities influence the optimal choice of cooperation.

All of these papers have at most one dimension of informational asymmetry. Only a few papers examine contracts in a setting with multidimensional types, i.e., where an agent is defined by its characteristics on several dimensions that affect its valuation for a (basket of) good(s). Salanié (1997) refers to several papers that have studied multidimensional types but warns that the effort becomes fairly involved. Rochet and Stole (2001) argue that multidimensionality is problematic because the incentive compatibility constraints, which ensure that each agent type chooses the contract that was designed for its type, may not only be locally binding