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Optimal exercise of jointly held real options: A Nash bargaining approach with value diversion ☆

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ABSTRACT

This paper provides a two-stage decision framework in which two or more parties exercise a jointly held real option. We show that a single party's timing decision is always socially efficient if it precedes bargaining on the terms of sharing. However, if the sharing rule is agreed before the exercise timing decision is made, then socially optimal timing is attained only if there is a cash payment element in the division of surplus. If the party that chooses the exercise timing can divert value from the project, then the first-best outcome may not be possible at all and the second-best outcome may be implemented using a contract that is generally not optimal in the former cases. Our framework contributes to the understanding of a range of empirical regularities in corporate and entrepreneurial finance.

1. Introduction

Many real option problems involve two or more parties that can generate a surplus by jointly exercising an option. In such cases, the option can only be exercised if the parties agree on the timing of the exercise and on the rule how to divide the proceeds. For example, when several firms enter into a joint venture to develop an oil field, they have to agree not only on how they will share revenues when extraction starts, but also on when to invest in order to start the extraction. Similarly, when biotechnology firms engage in joint R&D projects, they need to agree on the timing of capital injections as well as their economic stakes in the projects. Finally, in the context of mergers and acquisitions, an acquirer and target both care about the timing as well as the terms of a merger between the two firms.

Some of the real-world scenarios have already attracted attention and are separately examined in the literature. Cvitanić, Radas, and Šikić (2011) study optimal time of entry in the case of a cooperation, such as a joint venture, on a new product development between a large company and an entrepreneurial firm. Lambrecht (2004) analyzes a merger between two firms.[1] In this case, the payoff from the option exercise is the difference between the combined firm value and the sum of the values of individual firms with no option to merge. The strike price of the option is equivalent to the sum of fixed (irreversible) costs that each of the firms has to incur when merging. Also, an expansion of the firm financed by debt (cf. Mauer & Sarkar (2005), Sundaresan & Wang (2007) and Hackbarth & Mauer (2012)) can be interpreted as a joint real option exercise. In this case, two parties have to agree on terms of debt repayment, which directly influences investment timing.

Despite the multitude of situations in which a real option can effectively be jointly held by two (or even more) parties, a comprehensive analysis of joint exercise strategies has not been undertaken so far. In this paper, we develop a simple yet general framework that embeds typical contractual arrangements analyzed in the extant literature as its special cases and derive their efficiency implications for decision making. We subsequently use the proposed framework to rationalize various types of contracts observed in economic practice.[2]

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[1] Related contributions to the literature on mergers and acquisitions include Morellec and Zhdanov (2005), Alvarez and Stenbacka (2006) and Lukas, Reuer, and Welling (2012).

[2] We abstain from analyzing a related but distinct situation in which parties *compete* against one other to be first to exercise a non-exclusive real option. Chevalier-Roignant, Flath, Huchzermeier, and Trigeorgis (2011) provide a recent comprehensive survey of this stream of literature.

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We start off by analyzing the optimal exercise policy of a real option that is jointly held by two parties (firms).[3] In particular, we employ a two-stage decision-making framework in which the parties determine the sharing rule as an outcome of Nash bargaining and one of them makes the exercise decision.[4] In terms of the sharing rule, we consider cash transfers as well as ownership stakes in the project.[5] To capture two different types of contractual arrangements present in the literature, we contrast the scenario in which the exercise decision is made first with the one in which it is the division of proceeds that precedes the exercise decision. We subsequently extend the framework to allow for the real option to be held jointly by any number of parties and demonstrate that the results derived for two firms continue to hold. Finally, we analyze a situation in which the party that chooses the investment timing is able to divert a fraction of the project value at a deadweight cost.

We find that when the exercise decision is made first, timing is always socially (and individually) optimal. It is irrelevant which firm makes the investment decision and how bargaining power is distributed among the firms. Furthermore, the result holds even if cash transfers are not allowed for as well as in the case in which the firm that makes the exercise decision simply buys out the stake of the other firm. One special case of this result, with the ratio of the firms' bargaining power coefficients being equal to the ratio of their respective exercise costs, corresponds to the friendly merger discussed in Lambrecht (2004) as well as to Morellec and Zhdanov (2005). If we interpret the model such that one party represents an entrepreneur and the other an investor, the result implies that the entrepreneur always invests optimally regardless of the way he finances the project.

In the opposite case, when the sharing rule is determined first (as, among others, in the hostile takeover scenario of Lambrecht (2004) as well as in Mauer & Sarkar (2005), where a loan commitment is made), investment timing is socially inefficient unless a combination of a stake in the project and a cash transfer is used. In this case, it generally matters which firm makes the exercise decision and what amount of bargaining power it wields. A key implication is that the party exercising the option, e.g., the entrepreneur, is no longer indifferent between the financing choices and may generally invest inefficiently early or late.

We also find that the firm that makes the exercise decision almost always prefers to determine the sharing rule first such that it obtains full rights to the project by making a cash transfer to the other firm upon investment, which it inefficiently delays. If that firm is an entrepreneur, this suggests that he almost always prefers (riskless) debt financing where terms are fixed before the investment (debt commitment).[6] We show that equity financing can be rationalized when we extend our framework to allow for the possibility that the entrepreneur can divert part of the project's value at the time of investment.

The present paper studies optimal exercise of jointly held real options in a two-stage decision-making framework. Other contributions featuring such a framework include Shibata and Nishihara (2011) and Lukas et al. (2012), next to earlier discussed Cvitanić et al. (2011), Lambrecht (2004) and Mauer and Sarkar (2005). Shibata and Nishihara (2011) study a setting in which the level of managerial effort is determined first and the exercised decision is made second. In Lukas et al. (2012), who study contingent earnouts in mergers and acquisitions, the timing of the takeover is set first, and the target firm only then chooses its level of post-takeover cooperation. Our paper is different from these contributions in that it interacts the sharing rule decision with the decision to exercise the option to invest and the interaction takes place in a broad framework that can be applied to different settings. It also adds to the literature by demonstrating the efficiency implications of the sequence in which the decisions take place, the type of financial contract used, and the value diversion threat.

Bargaining over terms of investment in our framework is comparable to the way buyers and sellers negotiate over terms of trade in a supply chain (Nagarajan & Sošić, 2008). The scenario in which bargaining precedes timing decision is similar to a situation when the wholesale price is fixed first and procurement takes place at a later date (Caldentey & Haugh, 2009). Furthermore, contracts considered in this paper show similarities with those used in studies of coordination in decentralized supply chains. For example, a contract that allows one firm to retain full stake in the project by compensating the other firm with a cash transfer is akin to a wholesale price contract, and the one that combines a stake in the project with a cash transfer is like a revenue sharing contract in which a supplier obtains a share of retail profits by charging a retailer a lower wholesale price.

Then, our finding that a combination of a stake in the project and a cash transfer leads to investment efficiency is consistent with the result that revenue sharing contracts can coordinate supply chains (Cachon & Lariviere, 2005; Giannoccaro & Pontrandolfo, 2004). The value diversion threat in our framework can be likened to the selling effort of the retailer (Gurnani, Erkoc, & Luo, 2007; Taylor, 2002). Finally, two recent papers study optimal time to invest by establishing a supply chain.[7] Chen (2012) analyzes a case in which a supplier and a retailer cooperatively determine the optimal entry time when there is demand uncertainty. Lukas and Welling (2014) model the optimal timing of "climate-friendly" investments in a supply chain. In comparison to these recent contributions, this paper allows a larger contracting set, a value diversion threat and the variation in the sequence of events. Its framework is useful in analyzing contracting problems in the context of mergers and acquisitions, joint ventures, venture capital investments, and loan commitments as well as supply chains.

The remainder of this paper is organized as follows. We describe our basic set-up in Section 2. The exercise policy is presented in Section 3 and the possibility of value diversion is introduced in Section 4. Section 5 concludes.

2. Basic set-up

We begin the analysis with a simple case where two parties, i and j, jointly hold a real option to invest in a project. The project requires from each of the parties an irreversible investment outlay of I_i and I_j, respectively (investment outlay may include both monetary as well as a non-monetary contribution). The project value, which is V_t at time t, follows a geometric Brownian motion:

$$dV_t = \alpha V_t dt + \sigma V_t dz_t \tag{1}$$

[3] Where appropriate, we use terms "firms" and "parties" interchangeably.

[4] We subsequently analyze implications of an assumption that both parties have to agree on the exercise trigger. Moreover, the fact that firms may already receive cash flows from existing assets is irrelevant in Nash bargaining as it is the difference between new and existing cash flows that matters. Therefore the latter can be easily normalized to zero so the solution is interpreted in terms of sharing the *surplus*.

[5] Similar contractual forms are examined in de Bettignies (2008). While this paper focuses on optimal exercise of jointly held real options, de Bettignies focuses on the issue of effort complementarity in a discrete-time setting with no discretion over the investment timing.

[6] As we explain below (riskless) debt financing is equivalent to the entrepreneur making a cash compensation to the investor in return for his input in the project (which may include both monetary as well as a non-monetary component).

[7] Other type of real options (or flexibilities) in supply chains include reordering and return options (Wu & Kleindorfer, 2005; Burnetas & Ritchken, 2005), option to switch supplier (Kamrad & Siddique, 2004), and flexibility to relax the retailer's budget constraint (Caldentey & Haugh, 2009).