



# Time to complete and research joint ventures: A differential game approach

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## Abstract

In this paper we analyze cooperation in R&D in the form of research joint ventures (RJVs). We show that the optimal size of an RJV does not only depend on the degree of spillovers, as literature suggests, but also on the cost function of R&D activities. Moreover, the explicit consideration of the fact that R&D projects take time to complete shows that benefits from cooperation in R&D not only allow RJVs to carry out larger R&D projects, but also to reduce the time to completion for projects with a given size and, consequently, to accelerate the acquisition of the benefits associated with the innovation.

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## 1. Introduction

The study of innovations has become an important area of research in the economic literature due to its contribution to economic growth. However, there

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exists a series of market failures related to the research and development (R&D) activity including for instance the problem of appropriability or the duplication of effort<sup>1</sup> that could undermine incentives of innovators to undertake research investments. Therefore, governments apply a set of policy instruments to correct these market imperfections. A policy that has received attention in the recent past has been the promotion of cooperative R&D. Aside from enabling the participants to overcome a cost-of-development barrier impenetrable to any of them alone, one advantage of cooperative R&D is the elimination of duplication of effort. As pointed out in [Benfratello and Sembenelli \(2002\)](#), research joint ventures (RJVs) are commonly seen as a potential solution to the small amount of resources invested in R&D activities in Europe and to the low productivity of these resources. Framework Programs for Science and Technology (FPST) and the EUREKA program are examples of these policies in the European Union.

Recent years have witnessed the development of a large literature analyzing cooperation in R&D activities. For a survey of different kinds of inter-firm partnerships, see [Hagedoorn et al. \(2000\)](#) and [Hagedoorn \(2002\)](#). In the theoretical literature papers studying cooperation in R&D include, for instance, [Katz \(1986\)](#), [D'Aspremont and Jacquemin \(1988\)](#), [Kamien et al. \(1992\)](#), [Suzumura \(1992\)](#), [Petit and Tolwinski \(1999\)](#), and [Cellini and Lambertini \(2002\)](#). Several forms of RJVs have been studied in the literature where, while sharing the outcome of their R&D efforts, firms can decide unilaterally on their R&D investments, or they can coordinate them in order to maximize the sum of overall profits (RJV competition and RJV cartelization). In the latter case they internalize the effect that the R&D effort of one firm has on the profits of the other firms in the RJV (the so-called combined-profits externality), and consequently the amount of profitable R&D investments that firms are able to carry out is higher.

However, if firms are analyzing the investment decision in a R&D project of a given size, and this project is profitable for an RJV independent of the way that firms adopt investments decisions, a question arises: is there some additional criterion that could help them to decide on which is the best organizational structure? In order to study this question we analyze the effects of the inclusion of time to complete<sup>2</sup> in the R&D process. While in many papers it is assumed that R&D expenditures lead to immediate effects (see, e.g., among many others, [Cellini and Lambertini, 2002](#)), either in product differentiation or in cost reduction, in reality it takes time to develop a breakthrough. As pointed out in [Martin \(1994, p. 362\)](#), 'Like all investment projects, R&D involves time in an essential way. A firm seeking to develop a new technique or product must sink its funds into the project for some time before it profits from lower costs or revenues from the sale of a new product'.

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<sup>1</sup>For a review of the theoretical and empirical literature on the R&D activity, see for instance [Kamien and Schwartz \(1982\)](#), [Cohen and Levin \(1989\)](#), [Reinganum \(1989\)](#), [Cohen \(1995\)](#), and [Sena \(2004\)](#).

<sup>2</sup>The issue of time to complete in an R&D project was also analyzed in, e.g., [Miltersen and Schwartz \(2004\)](#) in a two-decision maker framework and [Kort \(1998\)](#) in a one-decision maker framework, but where these papers concentrate on uncertainty, we undertake a game theoretic approach within a deterministic framework.

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