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A PRIMER ON R&D COOPERATION AMONG FIRMS

by Marco Marinucci*

Abstract

This paper provides an introduction to the economic analysis of R&D cooperation among firms. Basing on some stylized facts, we survey the relevant theoretical literature in order to discuss the benefits and the costs that firms face when they cooperate in R&D. We then analyze the pros and the cons of R&D cooperation from a policy-making perspective. We find that R&D cooperation is usually considered welfare improving and can be promoted by several policies. Finally, we discuss paths of research not yet taken in the theoretical literature.

JEL Classification: O30, L40, L24.
Keywords: R&D cooperation, R&D spillovers, welfare, innovation.

Contents

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"Competition has been shown to be useful up to a certain point and no further, but cooperation, which is the thing we must strive for today, begins where competition leaves off." (Franklin Delano Roosevelt 1882-1945)

1 Introduction

[1] In his well-known book, Tirole [1988] stated that "In addition to the desirable development of operational welfare criteria, two other R&D-related matters are wide open for further exploration... [Among them] formal agreements between firms (e.g. licensing or joint research ventures) play a non-negligible role in the conception and diffusion of new technologies" (Chapter 10 p. 409). Twenty years on, firms' R&D cooperation has become a very active field of investigation in both business and industrial organization studies (Sena [2004]).

As noted by numerous surveys of the literature,[2] this keen interest on the part of academics is mainly due to the topic's increasing economic relevance. R&D alliances among firms have grown exponentially in recent decades.

As Cabral [2000] points out, the R&D alliances formed in the US increased from 750 in the 1970s to 20,000 in 1987-1992. Likewise, Hagedoorn [2002], analyzing the MERIT/CATI database, shows that the number of alliances formed each year in the world rose from several hundred in the 1970s to thousands in the late 1990s.

The increasing cooperation among firms in R&D is confirmed for sectors such as pharmaceuticals and biotech (Roijakkers and Hagedoorn [2006]) as well as for public R&D programmes (e.g. Roediger-Schluga and Barber [2006]). However, in both business and economic studies, the increasing number of R&D partner-

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[2] Among others, see Hagedoorn et al. [1999], Caloghiour et al. [2003], Sena [2004], and more recently Silipo [2008]. See also Todeva and Knoke [2005] for a review of the business literature.

ships attracts as much interest as does their heterogeneity.

A good many studies seek to understand the main benefits that firms get when they cooperate with partners that differ in their location (domestic vs. foreign),[3] size (large vs. small),[4] market relationship (customers, suppliers, competitors)[5] and nature (private vs. public).[6]

This focus is due to the fact that partners' heterogeneity implies different needs and, consequently, various types of partnership depending on the degree of cooperation that firms want for their R&D alliances: partners can choose to form an independent entity (i.e. research joint ventures (RJVs)) in order to coordinate their R&D activity,[7] or they can adopt non-equity forms of cooperation like cross-licensing, patent pools, and research-sharing joint ventures[8] that do not require the formation of a third entity but only the sharing of R&D information and/or results. Moreover, they can cooperate by participating in R&D coalitions (research consortia, patent pools, RJVs, etc.) or, alternatively, by forming a network of more informal or non-transitive R&D partnerships (cross

[3]Actually, there are relatively few theoretical works that analyze the formation of R&D partnerships in an international setting. Among them the most notable are Brander and Spencer [1983] and Motta [1996]. For an empirical investigation see Loof [2007], who studies a Swedish sample, finding that multinational enterprises get more benefit if their research collaboration is oriented toward the host country and/or is formed with scientific partners.

[4]For an interesting discussion on the relationship between R&D cooperation and firm size see Barba-Navaretti et al. [2002] and Roller et al. [2007].

[5]For a detailed analysis see Belberdos et al. [2004], who find that the firms' incentive to cooperate depends significantly on the nature of the partner (i.e. competitor, customer, supplier, university). Similar results are reported by Veugelers and Cassiman [2005] for a Belgian dataset

[6]On R&D cooperation among firms and universities see Lee [2000], Caloghirou et al. [2001], Belberdos et al. [2004] and Veugelers and Cassiman [2005].

[7]Actually, the degree of R&D coordination can differ markedly according to organizational structure of the RJV. For example, in the economic literature studies have investigated the different economic (and policy) implications of forming an RJV as a single joint lab rather than two separate ones. For further references on this topic see Kamien et al. [1992] and Amir and Wooders [1999].

[8]As defined by Greenlee [2005], in these arrangements partners just share their knowledge without the need of coordinating their R&D activity to maximize their joint profits.

-licensing, research-sharing joint ventures, etc.).[9]

Given such heterogeneity, it is not surprising that both empirical and theoretical studies examine these forms of cooperation in order to understand when and why partnering firms choose one type of cooperation rather than others.

From this point of view, the technology an industry uses seems to influence firms' decision to form one type of partnership rather than another. The number and the type of R&D alliances differ across sectors: alliances are very common in high-tech industries and quite rare in low-tech ones.[10] This is confirmed by Moskalev and Swensen [2006], who find that the most "cooperative" sectors are technology-intensive (pharmaceuticals, electronics and equipment, telecommunications, etc.),[11] as well as by Hagedoorn [2002], who finds that the high-tech sectors' share of R&D partnerships exceeded 80% in 1998. However, together with this quantitative difference, there is also a qualitative difference insofar as some industries tend to have non-equity forms of R&D cooperation while in others firms prefer to cooperate by forming RJVs.[12]

Another stylized fact that goes together with the steady growth of R&D alliances and their heterogeneity is their strong clustering in both industries and public R&D programmes. Roijakkers and Hagedoorn [2006] find evidence of this for the R&D partnerships formed in the pharmaceutical and biotech sectors from 1975 to 1999, while Hanaki et al. [2010] also support it with regard to R&D cooperation between U.S firms in the IT industry from 1985 to 1995. In a similar vein, Roediger-Schluga and Barber [2006], examining the alliances formed within the European Framework Programme,[13] find a strong clustering

[9]The theoretical literature has not yet analyzed why some firms build up informal networks and participate in R&D consortia at the same time. For an interesting attempt in this direction see Caulier et al. [2009].

[10]It is worth mentioning that before the 1980 most R&D partnerships were concentrated in mid-tech sectors. See Hagedoorn [2002], Figure 3, p. 482.

[11]See Moskalev and Swensen [2006], Table 3, p. 38.

[12]For example, comparing the use of cross-licensing with respect to other forms of alliance, Anand and Khanna [2000] find a pronounced difference between the electronics and computer sectors and the chemical industry.

[13]The Framework Programme, promoted by the European Commission since the 1984, aims at fostering cooperation among European firms and public research institutions. Its importance has increased with the so-called Lisbon strategy. In particular, it is the main tool

around the most important and innovative European firms and universities.[14]

Given these stylized facts, R&D cooperation represents an interesting field to analyze, especially from a theoretical perspective. However, rather than making a detailed survey of the literature, this paper aims to provide a general analysis of why firms' form R&D partnerships, why governments are so interested in R&D cooperation, and how the literature addresses these questions from both a welfare and an industrial point of view.

The rest of the paper is organized as follows. In the next section we examine why firms cooperate in R&D, pointing out not only the benefits of R&D alliances but also their potential limits and drawbacks. Section 3 introduces the main welfare benefits, the potential social costs, and the policies bearing on R&D cooperation among firms. In Section 4 we discuss the research paths we consider worth pursuing in the near future. Section 5 concludes.

2 Why do firms cooperate in R&D?

2.1 Main benefits of the R&D cooperation

With R&D partnerships increasing in number and affecting most of the high- and mid-tech sectors, it is natural to ask why firms cooperate in R&D. The question is not trivial because R&D activity is a key to competitiveness in the final market, so one would expect firms to be reluctant indeed to share it with their competitors (Caloghirou et al. [2003]). The answer lies in some basic features of R&D activity that make cooperation an "attractive" opportunity.

First, R&D is subject to "technological" uncertainty: it is difficult for a firm to foresee whether its R&D effort will eventually provide a new productor technology. And even in case of a technological success, there is still a "commercial"

for the development of the European Research Area. See EU Commission [2006] for details.

[14] Actually, there is still an intense debate about the effectiveness of the Framework Programme: some academics judge its effect as positive (see for example Arnold [2005] and Atlantis [2004]) while others are more critics either because it is difficult to assess the benefits of the Framework Programme on firms' profits and social welfare (Lukkonen [1998] [2000]) or because the Framework Programme has an ambiguous effect on firms' productivity (Benfratello and Sembenelli [2002]).

uncertainty, the risk that a new technology is not attractive for consumers.[15]
Second, R&D activity is imperfectly appropriable, that is to say a firm's R&D result can be partially or totally exploited by its competitors without paying the related fee (Arrow [1959], Nordhaus [1962]). Even though these "R&D spillovers" may be socially desirable because they disseminate new inventions in society, they are also harmful because they reduce the firms' incentive to innovate.
Imperfect appropriability is even more serious insofar as the development of a new product or technology requires significant resources (machinery, prototypes, experiments etc.) while, with the exception of particular technologies where reverse engineering may be difficult, the transmission and the learning of the R&D results are low (Arrow [1959], Nordhaus [1962]).
As a consequence of the potential leakage of R&D "production" and its relative low cost of transmission, firms' R&D effort may be lower than the level desirable from a welfare point of view.
Can these problems explain why firms cooperate in R&D? Intuitively, cooperation in R&D is profitable because it somehow solves the problems mentioned above. Obviously, multiple types of R&D partnerships imply different ways of solving them: equity alliances (RJVs and research consortia) are less flexible than "weaker" non-equity forms of cooperation (cross-licensing, patent pools etc.), but they may lead to profitable synergies among partners.

2.2 Literature review

At this point of the analysis it is worth seeing how the economic literature explains why R&D partnerships are (sometimes) profitable. The advantages of R&D cooperation have been widely discussed in the industrial organization theoretical literature from several points of view. However, since the industrial organization and business literature is extensive,[16] we will provide just a sketch of what we view as the main studies and results in the theoretical literature on R&D cooperation under the headings of the problems relating to R&D activity: R&D spillovers, uncertainty, and high R&D costs.

[15] For example, even though it was technologically superior, the Betamax video-recording technology was commercially "defeated" by the VHS standard in the early of the 1980s.
[16] See for example Kogut [1988], Caloghirou et al. [2003] and Sena [2004].

R&D spillovers The relationship between RJVs and R&D spillovers has been widely studied. To the best of our knowledge, the first model that confirms this relationship is that of Katz [1986], who examines the possible benefits of RJVs according to the degree of R&D spillover, the degree of market competition, and the number of firms participating in the RJVs. The literature blossomed thanks to the seminal paper by d'Aspremont and Jacquemin [1988],[17] which shows that firms find advantageous to cooperate in R&D because it allows them to internalize the R&D spillover inefficiency and to eliminate R&D effort duplication. Kamien et al. [1992] were among the first to extend and generalize the d'Aspremont-Jacquemin model by a) adopting a more general demand function and b) studying how a different degree of spillover within the partnership can influence RJV profitability. Interestingly, even though they seem identical in their approach, Amir [2000] shows that the use of different strategic variables (R&D expenditures rather than unit cost reduction) in the analyses leads the two models to different results and policy implications.

Starting from d'Aspremont and Jacquemin [1988] and Kamien et al. [1992], a first strand of the literature studied the RJVs created to obtain product innovation (e.g. Motta [1992], Cabral [2000], De Fraja and Silipo [2002], Lambertini et al. [2003]),[18] confirming the d'Aspremont-Jacquemin model's results, namely that the RJV is profitable especially when the R&D spillover level is particularly high.

Other papers investigated the existence of asymmetric R&D spillovers among the competing firms either by considering different spillover levels enjoyed by the firms (De Bondt and Henriques [1995]) or by looking at the extreme case of one-way spillovers (Amir and Wooders [1999] [2000]). All these papers find that firms may prefer to make asymmetric amounts of R&D investment but they have the drawback of imposing exogenous asymmetric R&D spillover levels. This assumption can be realistic under a leader/follower framework but it

[17] See Henriques [1990] and d'Aspremont and Jacquemin [1990] for, respectively, a comment and an erratum.

[18] Excluding Motta [1992], these paper are actually more interested in the relationship between RJVs and anti-competitive behaviour. Accordingly, we will discuss them in Section 2.3

does not clarify which degree of asymmetry leads to an equilibrium that is preferred to the classical symmetric one proposed by d'Aspremont and Jacquemin. Another strand of the literature aims to overcome this limit as well as the assumption made in the d'Aspremont-Jacquemin model that firms will always maximize their internal information-sharing when they cooperate in R&D. Katsoulacos and Ulph [1998] demonstrate that R&D partners do not maximize their information-sharing when this leads to excessive competition in the final markets. On the other hand, Kamien and Zang [2000] study how an RJV influences both partners and industry profits taking into account the R&D absorptive capacity.[19] Their analysis is based on the empirical evidence that the absorptive capacity influences the information sharing (when firms cooperate in R&D) as well as the actual R&D spillover degree enjoyed by firms (when they compete in R&D). The authors find that, since firms' absorptive capacity depends on the nature (broad vs. firm-specific) of their R&D effort, firms choose their research paths according to their decision to cooperate/compete in R&D: a broad research path when they cooperate, a narrow one when they compete. Last but not least, Lambertini et al. [2004] consider the case where firms can actually control the degree of the information leakage, in order to assess the R&D spillover effect on firms' performance when they compete/cooperate. Their analysis is both theoretical and empirical; they find that R&D spillovers are not under the full control of firms and that R&D cooperation may increase information-sharing among partners.

A different type of endogenization is introduced by Salant and Shaffer [1998], who prove that, under certain conditions on both the R&D cost function and the degree of the R&D spillover, an asymmetric equilibrium can arise even though partners are ex-ante symmetric. In particular, they show that in a RJV partners may prefer to provide asymmetric R&D efforts without changing their total amount of R&D investment. In such a case, partners would get higher profits when the spillover is low and, for some research cost functions, without affecting consumers' welfare. Other important contributions to the debate on asymmetric vs. symmetric equilibria are made by Amir and Wooders [1998] [2003]. The earlier work is particularly interesting in that it proves that, un-

[19] [20]

der some conditions, the reaction curves of firms' R&D effort may lead to an asymmetric "R&D competitive" equilibrium that firms may prefer with respect to the symmetric "R&D cooperative" equilibrium. In other words, rather than cooperate in R&D that leads to a symmetric equilibrium, firms choose not to cooperate, with one firm saving on the R&D investment and the other getting a higher share of the final market.

In recent years a different approach has been taken to try to overcome one of the main limits of the literature based on the d'Aspremont-Jacquemin model, with the use of a deterministic R&D cost function.[21] However, independently of the research paths, the common result of this literature is that RJVs can be a profitable way to internalize information leakages among competing firms, especially when the R&D spillover level is high.

Uncertainty, complementarity, and weak cooperation As Martin [2003] points out, even though the uncertainty in R&D plays a significant role in the creation of R&D partnerships, most of the theoretical models on R&D cooperation adopt a deterministic relationship between the R&D effort and the results obtained by a firm. Good examples of non-deterministic analyses are the simple frameworks proposed in Marjit [1991] and Combs [1992], which examine the conditions under which partners may profitably form a joint lab, given the probability of succeeding in discovering one or more innovations. In particular, the main finding of the former paper is that two firms have the incentive to form a joint lab only when the probability of success is either low or high. Combs [1992], extending Marjit [1991] by allowing the formation of multiple research joint labs among partnering firms, shows that R&D cooperation is profitable only when the probability of success is sufficiently high.

The non-deterministic approach has also been taken in more complicated models, for example in Miyagiwa and Ohno [2002], who show that if industry profits are higher through the R&D cooperation, then R&D alliances are always profitable, and in Erkal and Piccinin [2010], whose structure is based on the patent race framework la Loury [1979]. Erkal and Piccinin's paper is particularly inter-

[21] Good examples of this alternative viewpoint are Jansen [2010], Martin [1995] [2006], Miyagiwa and Ohno [2002] and more recently Erkal and Piccinin [2010], whose contributions will be discussed at the end of the next section.

esting insofar as it is the first to study the profitability of R&D alliances under stochastic R&D and free entry in both the R&D race and the final market. With this framework, it establishes that R&D cartels[22] are never profitable, and that the profitability of RJV cartel (i.e. when firms share R&D efforts and maximize their joint profits) is inversely related to the size of the cooperation agreement. Using a different approach, Letterie et al. [2008] consider R&D partnerships as a tool to share information that mitigate the uncertainty surrounding a new technology to be discovered. The authors find a positive relationship between that uncertainty and the number of R&D alliances formed by each firm. However, assuming the existence of redundancy in the information held by the potential partners, the authors find that the willingness to form alliances decreases as such redundancy increases, a result indicating that the success of an R&D alliance depends on the type of partners that a firm selects.

The issue of what kind of partner a firm should choose has been treated quite extensively in the economic literature from both an empirical and a theoretical point of view. Some attention has recently been devoted to R&D partnerships between firms and universities. Empirical studies of this topic include those by Lee [2000], Caloghirou et al. [2001], Scott et al. [2002], Veugelers and Cassiman [2005], and more recently Lacetera [2006]. Nevertheless, firm-university R&D alliances have not been investigated in the theoretical literature.

Actually, some theorists pay attention to the potential partners' synergies by looking at their complementary skills, e.g. Belleflamme and Bloch [2000], Anbarci et al. [2002], and Cowan and Jonard [2008]. In spite of their different frameworks,[23] these papers find that R&D cooperation is successful only when there is some but not too much complementarity among partners' skills.

Although no theoretical papers examine how and when firms and universities can profitably cooperate, several empirical papers do investigate this issue (e.g. Kleinknecht and Reijnen [1992], Hernan et al. [2003], and Miotti and Sachwald

[22]Following the definition in Kamien et al. [1992], "R&D Cartel" means that firms coordinate their R&D efforts to maximize their joint profits without sharing their information.

[23]As a matter of fact, Belleflamme and Bloch [2000] proposes a double-sided moral hazard model; Anbarci et al. [2002] extends the Kamien et al. [1992] contribution, while Cowan and Jonard [2008] adopts an approach based on network games.

[2003]). They suggest that the rationale for cooperating with a university is usually different from the reasons for cooperating with a competitor because universities have know-how and research skills that other firms cannot provide. Other scholars look at R&D cooperation from an international point of view. To the best of our knowledge, Motta [1996] is the first study the formation of international RJVs using a model of the d'Aspremont-Jaquemin type. It considers the case of two couples of firms, each of them established in two different countries. The author proves that R&D cooperation between firms of the same nation has an impact on their international competitiveness similar to an R&D subsidy. This means that from a strategic trade policy viewpoint, encouraging R&D cooperation among domestic firms can be seen as an alternative to export subsidies as suggested by Brander and Spencer [1983] with an important difference: if both countries foster R&D cooperation between their own firms, their welfare improves; this result is in sharp contrast with the worsening of national welfare that occurs when both countries adopt the other trade policies like export subsidies.

Another interesting contribution is that of Lin and Saggi [2004] who consider a moral hazard framework to show that the partners' incentive to upgrade the technology they provide in an international RJV is sensitive to who decides on the RJV profit sharing (partners vs. local government). More recently, Poyago-Theotoky and Teerasuwannajak [2009] find that different regimes of intellectual property rights may increase information-sharing between firms operating in different countries.

Reflecting the increasing share of weak partnerships (Hagedoorn [2002]), the literature on R&D cooperation has recently focused on non-equity partnerships. One approach is based on the "network game" as defined by Jackson and Wolinsky [1996]. In R&D networks, players are firms, a link is a profitable R&D partnership and the whole network represents the existing R&D partnerships among the firms. Among the most important papers in this body of research are those by Goyal and Moraga [2001], Goyal and Joshi [2003], and Deroian and

Gannon [2006]. Unlike coalition game models,[24] network game models allow the non-transitivity of the R&D links, namely the possibility that a firm can form a new alliance without the consent of its current partners. Consequently, while the coalition game approach is more suitable for describing strong forms of R&D cooperation, R&D networks are more able to describe weak R&D alliances.

A second group of models focuses on patent pools, agreements whereby partners share their patents in order to create a standard technology, with the aim of exploiting the pool for their own research activity and/or selling it to other firms in exchange for a unique fee. Good examples are Choi [2003], Dequiedt and Versaevel [2007], and above all Lerner and Tirole [2007], who show that patent pools are anti-competitive only when they include substitute patents. It is worth mentioning that although patent pools date far back, this literature is very recent because patent pools were considered anti-competitive until the end of the 1990s.[25]

2.3 Limits and drawbacks of the R&D cooperation

Although R&D alliances bring many benefits, they still have drawbacks that can call their profitability into question. Three main problems can be identified.

First, the search for complementary skills via R&D partnerships does not guarantee perfect results. Each firm has to choose a partner whose know-how is useful for its objectives. However, since partners' objectives and know-how are only partially known, an R&D alliance can fail because of their mismatch.

Second, R&D partnerships are subject to moral hazard insofar as one firm may have an incentive to reduce its effort (e.g. by providing low-quality personnel or equipment) and enjoy the partners' R&D effort inside the alliance. This topic is addressed by Espinosa and Stadler [2003], who study how the intensity of moral hazard influences the formation of R&D coalitions among firms that compete la Cournot in the final markets. Together with the previously mentioned work by Lin and Saggi [2004], it is also worth noting the study by Fabrizi and Lippert

[24] The coalition game approach has been used to study how profitability and welfare depend on the number of members of the RJV and of market competitors. See Simpson and Vonortas [1994], Greenlee and Cassiman [1999], and Yi and Shin [2000] for examples of analysis of R&D cooperation using a coalition game approach.

[25] See Gilbert [2002] for a historical review.

[2007], who focus on the different firms' incentives to form either an RJV or a cross-licensing agreement as the moral hazard level increases.

Third, the formation of an R&D alliance has to be evaluated taking into account that the profitability of the cooperation is sensitive to the organization as well as the strength of the alliance that a firm wants to form. Moreover, when the number of arrangements becomes significant, firms have to manage their portfolio of alliances according to a specific strategy, which is quite difficult to achieve (Mc Kinsey [2002]).

Summing up, the possible mismatch between partners, the moral hazard concerns and sensitivity to the organization of the partnership and to the portfolio of R&D alliances make R&D partnerships quite unstable and not always profitable. Although the business literature on the instability of the RJVs is voluminous,[26] the subject has not been widely addressed from a theoretical point of view.

3 Why do governments promote the R&D cooperation?

Social benefits of the R&D cooperation We have seen that firms create an R&D alliance in order to overcome the R&D spillover externality, to reduce the uncertainty surrounding R&D activity, and to find complementary skills that are not available within the firm. Nevertheless, governments and public institutions have also fostered the formation of R&D partnerships within and across countries. What motivates this public interest toward R&D partnerships?

The initial aim of many governments in promoting R&D alliances was to increase or maintain the international competitiveness of domestic producers. Relevant examples are Japan's VLSI and Semantech in the United States,[27] and the

[26] Among others, see Kogut [1988], Deeds and Rothaermel [2003], and more recently Duso et al. [2007].

[27] The VLSI (Very Large Scale Integration) programme was created in the late 1970s to develop a new generation of highly competitive Japanese semiconductors. The VLSI project was so successful that in the early 1980s the U.S. government promoted the Semantech con-

European programmes to boost the competitiveness of European firms in the information and technology sectors (ESPRIT)[28] and other fields of applied research (e.g. Eureka!).[29]

However, nowadays public programmes are created to boost the competitiveness of a whole country or of an economic area independently of the firms' nationality. For example, the EU Framework Programme, created to promote the research activity and increase the competitiveness of European firms, has recently been opened to firms operating outside Europe.[30]

This policy change leads us to the second reason, namely the difficulty that governments and international institutions encounter in promoting R&D "production": even though R&D investment is the main engine of economic growth for a country, R&D activity is subject to uncertainty, high costs, and spillovers that reduce firms' incentive to invest in R&D to suboptimal levels with respect to social needs. Encouraging cooperation solves this problem insofar as it increases firms' R&D investment, eliminates wasteful duplication, and makes firms' products cheaper or better so that the partners' profits and consumers' surplus increase.[31]

Therefore, from a microeconomic perspective, promoting R&D cooperation among firms can be a welfare improving policy. This is actually what has happened since the late 1970s in Japan and the 1980s in the U.S. and Europe, not only through the public programmes mentioned above,[32] but also with more

sortium to help U.S. semiconductor producers keep up with their Japanese competitors. See Katz and Ordover [1990] for an interesting and insightful comparison of the two programmes.

[28]In 1999, ESPRIT was succeeded by the Information Society Technologies (IST) programme, one of the key components of the 6th European Framework Programme.

[29]The Eureka! programme was created in 1986 to fundi applied research projects proposed by European business consortia. It uses a bottom-up approach and is funded by EU member states according to the nationality of each participating firm.

[30]See the Cordis website http : $http : //cordis.europa.eu/fp7/public_en.html$ for further details.

[31]In recent years policymakers have fostered R&D cooperation in favour of consumers' surplus rather than industry profits. For example, the objective of the 5th Framework Programme was to promote all projects able to improve the innovation capacity of firms and the welfare of EU citizens.

[32]EU investment in the Framework Programme rose from less than 18 billion for the 6th edition to more than 50 billion for the 7th edition.

lenient antitrust laws in favour of cooperative R&D agreements, and subsidies in favour of the formation of RJVs. Are these policies a panacea for the underprovision of socially optimal R&D investment? Looking at the benefits, policy makers would be induced to promote R&D cooperation unconditionally. Nevertheless, there are two crucial problems that governments and international institutions cannot ignore.

First, policymakers have to consider what are the ideal policy tools to stimulate the socially optimal level of R&D: can public R&D programmes increase the innovative capacity of its participating firms? Can more lenient antitrust rules facilitate the formation of socially optimal RJVs?

Second, governments and international institutions have to face the risk that firms, especially competitors, might use R&D partnerships for anti-competitive conduct, such as like lowering their R&D effort, pricing restrictions, etc.

Effectiveness of the R&D cooperation Concerning the first issue, many studies examine the effectiveness of subsidies and public programmes to promote R&D cooperation. For example, Leahy and Neary [1997] study whether subsidies for R&D partnerships positively affects welfare. Their main finding is that the profitability (hence the formation) of an RJV is independent of the subsidy received from a government. Consequently RJVs should not be subsidized. An opposite result is obtained by Yi and Shin [2000], who adopt a coalition formation game to prove that the R&D grand coalition is always welfare improving, but is never stable because of the firms' free-riding. In such a case, promoting R&D subsidies is welfare improving because it leads to the formation of the grand coalition, which represents the socially optimal best solution.[33] Hinloopen [2000] compares direct R&D subsidies with a policy that promotes the formation of RJVs. He finds that both policies lead to the same welfare levels but, as RJVs can also be formed for anti-competitive purposes,

[33]It is worth mentioning that part of the literature also investigates the optimal dimension of RJVs from both a social and private welfare perspective. Papers such as those of Simpson and Vonortas [1994], Poyago-Theotoky [1995], Greenlee and Cassiman [1999], and Yi and Shin [2000] find that the grand coalition is welfare improving, but not always stable. Others, e.g. Martin [1994], and Goyal and Moraga [2001], find that welfare can be maximized even for "smaller" coalitions.

R&D subsidies should be more desirable. Another interesting contribution is that of Cassiman [2000], who shows that when policymakers add a lump-sum subsidy to the allowance to form RJVs, they are able to screen the RJVs that improve welfare from the ones that are formed for anti-competitive purposes.

Turning to the empirical literature, Benfratello and Sembenelli [2002] find that firms involved in the Framework Programme obtained mixed results in terms of productivity gains whereas firms that participate in the Eureka! programme improved their productivity and efficiency. This finding can be read as showing the ineffectiveness of the Framework Programme, but it can also be interpreted as showing the difficulty of evaluating public R&D programmes. For example, Lukkonen [[1998] [2000] points out the problems in assessing the effectiveness of public R&D programs like the Framework Programme. Similarly, Falk [2007] uses an Austrian database to show that firms tends to revise their whole R&D strategies (effort, organization, length and dimension of their current projects, etc.) when they are applying for public R&D funding. This means that, independently of getting the public grant, firms can still obtain a benefit thanks to their R&D strategy reorganization. This suggests that the cause-effect relationship between public funding and firm's improved R&D productivity is not as straightforward as supposed in the economic literature.
Summarizing, both the theoretical literature and empirical studies do not provide a unique answer regarding the desirability of public support for R&D cooperation, albeit for different reasons: for the empirical literature evaluating public R&D programmes is difficult because their results feed through with a long lag and are therefore biased by other events, whereas the theoretical literature is more concerned about the anti-trust implications of R&D cooperation.

Anti-trust implications of the R&D cooperation Together with public R&D programmes and subsidies, several governments have stimulated the formation of R&D partnerships by providing more lenient anti-trust rules. For example, in U.S. A. the National Cooperative Research Act states that all firms willing to cooperate in R&D that file in a national register will be evaluated

by antitrust authorities under the rule of reason rather than the per se rule.[34] In a similar vein, patent pools are now tolerated after being considered illegal and socially harmful for decades (Gilbert [2002]). Therefore, it is natural to question whether such policy change is justified or not.

The literature on the possible anti-competitiveness of R&D partnership is fairly recent. Martin [1995] was the first to point out the possibility that firms may use R&D cooperation to make their collusive agreements more stable. For some years it was the only paper on the issue.[35] Since the turn of the century several papers have followed it. Some use a patent race model la Loury [1979], for instance Martin [2006] and Miyagiwa [2009]. Others are based on the multi-market contact model proposed by Bernheim and Winston [1990];[36] Lambertini et al. [2003] and Bacchiega et al. [2008] uses the classic d'Aspremont-Jacquemin framework while Cabral [2000] proposes a model with a generic (well-behaved) profit function in a repeated game contest. Independently of the approach, it is interesting to note that all these papers end up finding the potential anti-competitiveness of R&D alliances, suggesting that while governments can continue to support the formation of R&D partnership via subsidies and public R&D programmes without too many worries, more lenient antitrust rules are a policy route that needs to be treated with caution.

4 Directions for future research

A glance at the literature on firms' R&D cooperation may suggest that not much is left to study, but on closer examination we find that, after more than twenty years of discussion, the topic is still one of the most lively in the literature.

[34] At the turn of the 1990s Jorde and Teece [1990] proposed extending the rule of reason to the more general production joint ventures on the ground that innovation involves all the productive stages of the firm. For two interesting responses, see Brodley [1990], and Shapiro and Willig [1990].

[35] Actually, Martin's article prove that RJVs makes tacit collusion more stable, but he does not investigate the welfare effect, a topic later discussed in Martin [2002].

[36] Among them the most notable are Vonortas [2000] Matsushima [2001], and Snyder and Vonortas [2005].

One reason is the evolution that R&D partnerships have undergone since the 1980s: R&D alliances now mostly involve firms operating in high-tech industries, whereas in the 1980s R&D cooperation was between firms in medium-tech sectors. Furthermore, firms tend to form R&D partnerships that are more flexible than RJVs. Even from a policy viewpoint, patent pools are now tolerated (if not encouraged) by policymakers. Therefore, new models and theories are necessary to keep the pace with the evolution of R&D alliances. Despite the growing body of literature on patent pools and cross-licensing (Choi [2003], Lerner and Tirole [2007] ...) most works focus too narrowly on RJVs cooperation. Further studies of more flexible forms of cooperation are still needed.

A second reason derives from new developments that extend the possible research paths, notably the increasing cooperation between firms and public research institutions. Nowadays all the leading firms in medium- and high tech sectors are involved in cooperative agreements with universities or public research laboratories or both. This is due not only to strong policies in favour of R&D cooperation between the public and private sectors, but also to firms' efforts, under the pressure to become more competitive, to get access to new and complementary resources that their usual partners (suppliers, customers, competitors) lack. The economic analysis so far of these hybrid forms of cooperation is empirical (Belderbos et al. [2004], Caloghirou et al. [2001], Veugelers and Cassiman [2005]) and still requires a significant theoretical contribution.
Firms' cooperation in R&D has also been influenced by the TRIPs (Trade Related Intellectual Property Rights) agreements.[37] According to Leahy amd Naghavi [2006], the resulting strengthening of intellectual property rights has led multinational enterprises to enter into (research) joint ventures with local firms as an alternative to foreign direct investment. In spite of the relevance of TRIPs agreements for firms R&D cooperative strategies, there are still few theoretical works on international R&D cooperation, with the exception of Motta [1996] and several others.[38]

[37] See Sonderholm [2010] and references therein.
[38] Among them, Leahy and Naghavi [2006] and Song and Vannetelbosch [2007].

This leads us to a third reason for the importance of studying R&D partnerships. It is striking to see that topics like the stability of R&D partnerships are not yet taken up by economic theory whereas they are extensively studied in the business literature.[39] A deeper analysis of this topic would not only offer an alternative point of view but would also bridge the two literatures by providing a more general understanding of the causes and the effects of the instability of R&D alliances. A first step toward this analysis can come from studies that investigate under which conditions R&D cooperation arises. Good examples are Espinosa and Stadler [2003], Lin and Saggi [2004], Fabrizi and Lippert [2007], and Marinucci [2009].

Another important path that in our opinion warrants further investigation is the antitrust implications of R&D cooperation. The literature on this is already rich; nevertheless further analysis is necessary, especially considering that policymakers appear to adopt a schizophrenic attitude towards R&D cooperation: on one hand encouraging the formation of R&D partnerships, on the other forbidding (and punishing) any collusive behaviour in the final markets. Interestingly, Goere and Helland [2009] are the first to prove empirically that stricter antitrust rules on R&D cooperation reduce the probability that firms will create RJVs, implying that some RJVs are formed for anti-competitive purposes. Further analysis of the interaction of these policies on firms' R&D and collusive strategies is certainly desirable.

Finally, an important topic not yet discussed in the theoretical literature is the analysis of the alliance portfolios, first, because the increasing formation of R&D partnerships makes it difficult for firms to manage them in a proper way, and, second, because the topic increasingly discussed in the management literature.[40] A theoretical contribution would be useful to understand whether and how alliance portfolios influence firms' decision to ally with another one. Moreover, together with R&D partnership stability, R&D alliance portfolio analysis may

[39]See for example Makino and Beamish [1998], Deeds and Rothaemel [2003], Jang et al. [2008].

[40]For further references, see Nielsen and Mahnke [2009].

be another important link between the two fields.

5 Concluding remarks

In this paper we provide a primer on the economic analysis of R&D cooperation among firms. We begin in Section 1 by discussing the stylized facts on firms' R&D cooperation, highlighting the economic significance of the phenomenon, which justifies the interest of the (theoretical) economic literature in the subject. We then analyze the economic rationale that leads firms to cooperate in research and development (Section 2). To this end we also survey the literature review on R&D cooperation, showing that, though R&D cooperation can be profitable, there are limits and drawbacks that firms cannot ignore when they want to engage in an R&D partnership. Section 3 discusses the pros and the cons of R&D cooperation from the policymaker's point of view. Looking at the literature, we find that R&D cooperation is generally considered welfare improving, and that several policies can be adopted to promote a socially optimal level of R&D cooperation. Finally, in Section 4, we point out new research paths still to be taken in the theoretical literature. Despite two decades of economic analysis, some important aspects of R&D cooperation require further investigation.

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