Dynamic entrepreneurship: On the performance of U.S. research joint ventures

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Abstract:

In this paper, we present descriptive findings on the research success of U.S. research joint ventures (RJVs). Using survey-based data of a sample of U.S. RJVs, we build on the theory of dynamic entrepreneurship to develop an empirical model of cross-RJV differences in performance. We find that ventures that include a university as a research member are relatively more successful, measured in terms of research goals completed, than ventures that do not. We also find that those RJVs that have a longer research duration and that are led by a firm with prior RJV experience are similarly more successful. Our empirical analysis also shows that membership size is not a significant covariate with research success. We conclude the paper with a call for additional research and with a policy statement that is based on our finding of a positive and significant relationship between university membership and RJV success.

Keywords: research joint venture (RJV) | National Cooperative Research Act (NCRA) | R&D | universities | innovation | networks

Article:

Introduction

In the early 1970s, and then again in the late 1970s and early 1980s, the U.S. economy experienced a productivity slowdown. Total factor productivity (TFP) in the private business sector declined in 1973 and 1974, and then again during the period 1978 through 1982.¹

The Congress responded quickly to signs that the second productivity decline (1978–1982) was eminent and that it might be more pronounced than the first (1973–1974). In 1979, President Jimmy Carter commissioned the Domestic Policy Review on Industrial Innovation. Therein, President Carter announced:

¹ We have written about the antecedents and policy consequences of the productivity slowdown many times, so duplication of text and explanations, as in the following paragraphs, is unavoidable (Link and Link 2009; Leyden and Link 2015). As these references describe, there were several technology policy initiatives in response to the productivity slowdown, including, for example, the eventual passage of the Small Business Innovation Development Act of 1982, Public Law 97-219.

... measures which will ensure our country's continued role as a world leader in industrial innovation. By spurring competition, anti-trust policies can provide a stimulant to the development of innovation. ... The Department of Justice, at my direction, will issue a guide clearly explaining its position on collaboration among firms in research. ... This statement will provide the first uniform anti-trust guidance to industrial firms in the area of cooperation in research.

In 1980, in response to the President's directives, the Department of Justice (DoJ) issued *Antitrust Guide Concerning Research Joint Ventures*. The DoJ report states that (DoJ 1980, p. 3): "In general, the closer the joint activity is to the basic end of the research spectrum ... the more likely it is to be acceptable under the antitrust laws."²

After a series of legislative initiatives,³ the National Cooperative Research Act (NCRA) of 1984 (Public Law 98-462) was passed. A research and development joint venture, generally referred to as a research joint venture (RJV), was defined in the NCRA as follows:

Any group of activities ... by two or more persons for the purpose of

- (A) theoretical analysis, experimentation, or systematic study of phenomena or observable facts;
- (B) the development or testing of basic engineering techniques;
- (C) the extension of investigative findings or theory of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, prototypes, equipment, materials, and processes;
- (D) the collection, exchange, and analysis of research information; or
- (E) any combination of the purposes specified in subparagraphs (A), (B), (C), and (D), and may include the establishment and operation of facilities for the conducting of research, the conducting of such venture on a protected and proprietary basis, and the prosecuting of applications for patents and the granting of licenses for the results of such venture

Prefacing the Act is its stated purpose:

To promote research and development, encourage innovation, stimulate trade, and make necessary and appropriate modifications in the operation of the antitrust laws.

A registration process was created by the NRCA to indemnify participants in a RJV from certain antitrust actions. Specifically, if a RJV discloses to the DoJ its cooperative research intentions,

² Bozeman et al. (1986) and Link and Bauer (1989) developed a model that demonstrated that an output from R&D cooperation is additional R&D and that the additional R&D is toward the basic research end of the R&D spectrum. Leyden and Link (2015) extended these game theoretic models by using a neoclassical equilibrium approach to illustrate the implications from free riding versus cooperation.

³ A number of bills were introduced during the 98th session of the Congress. These initiatives led to the High Technology Research and Development Joint Ventures Act of 1983 and the Joint Research and Development Act of 1984.

including “the identities of the parties to such venture and the nature and objectives of such venture,” it will enjoy limited protection. Specifically, if the RJV was ever subjected to either criminal or civil antitrust action, those actions would be evaluated under a rule of reason criterion as opposed to a per se violation of antitrust law; and if the RJV failed a rule-of-reason analysis, it would be subject to actual damages rather than treble damages. The DoJ makes public each disclosure through the *Federal Register*. These disclosures contain the name of the RJV, the names of the members in the RJV, and a very brief description of the technology being researched.

The National Cooperative Research and Production Act (NCRPA) of 1993 (Public Law 103-42) amended the NCRA by expanding on what became known as the “safe harbor.” Specifically, the NCRPA extended indemnification to include joint production in addition to joint research.

Surprisingly, there is a conspicuous absence of information about cooperative research activity in the United States, in general, and about the performance of U.S. RJVs, in particular.⁴ This paper begins to fill that void by examining, in a descriptive manner, the relative research performance of one sample of U.S. RJVs. This paper is not an evaluation or even an assessment of the NCRA; rather, it is a step toward gaining insight about U.S. RJV performance. Specifically, we use survey-based data to document the relative research performance of U.S. RJVs and to identify a set of covariates that are predictive of that performance.

The remainder of the paper is outlined as follows. In Section 2, we describe our survey-based dataset, and we compare it to the population of U.S. RJVs as identified from the *Federal Register*. One of the main contributions of this paper is to present descriptive information on U.S. RJVs that is more detailed than that in the *Federal Register*, an effort that is conspicuously absent in the extant literature. To put this descriptive information in perspective, it is important to emphasize that a RJV is different from either an industry–university partnership or a research alliance. RJVs, especially those indemnified through NCRA and NCRPA, are generally formal contractual arrangements; this is generally not the case with research alliances (Vonortas and Zirulia 2015).

In Section 3, we discuss measures of RJV performance, and we offer several propositions about cross-RJV differences in such performance. Our propositions, which are the foundation for our empirical analyses, are motivated by the theory of dynamic entrepreneurship (Audretsch et al. 2016). We use the term *dynamic entrepreneurship* to refer to Schumpeterian innovativeness, and thus we focus on knowledge generated from human capital to examine RJV performance.⁵ As we discuss below with reference to the extant literature on RJV performance, the literature is thin and thus our descriptive evidence on performance and on possible covariates with performance is new to it. We also present descriptive statistics on the relevant variables to be used to test empirically these propositions about cross-RJV performance differences.

⁴ Eurostat collects information on the number of European firms collaborating on innovation activities, by size of firm as well as by R&D activity. These data are published at the country level by the OECD (2015). See also Link (forthcoming).

⁵ According to Audretsch et al. (2016, p. 609): “The distinction between dynamic and static entrepreneurship is innovation [and] human capital is the link between innovative activity and individual entrepreneurs.”

Our empirical findings are discussed in Section 4.

Concluding remarks are in Section 5. Our concluding remarks go beyond a summary of our findings. We suggest in the concluding section areas for additional research from an academic as well as a policy perspective.

Data on U.S. RJVs

In 1985, the year following the passage of the NCRA, the National Science Foundation (NSF) initiated an effort to document collaborations in innovation that are based on NCRA *Federal Register* filings.⁶ Then, in 1993, the NSF initiated the development of what it called the Cooperative Research (CORE) database, and the NSF continued to support its construction through 2007.⁷ The unit of observation in the CORE database is a RJV as defined by filings published in the *Federal Register*. Although the CORE database has limited information on each RJV, it documents the universe of federally recognized RJVs formed in the United States since 1985; the CORE database represents what is ostensibly the population of U.S. formal RJVs.⁸

Figure 1 shows the 1046 RJVs filed under the NCRA and the NCRPA by the year that the venture was publicly disclosed in the *Federal Register*.⁹ The number of RJV filings with the DoJ has noticeably decreased since their peak in the mid-1990s as shown in the figure. Drawing on the arguments set forth in Scott (2008), this decline might be due to firms realizing that the benefits of indemnification do not outweigh the costs associated with making public dimensions of their research strategy and/or it might be due to the fact that the DoJ has yet to file a case against firms collaborating in R&D. In recent decades, the courts have moved very decidedly toward recognizing the economic efficiency basis in joint efforts of firms, and for that reason, there might not be much of a reason for any RJV to worry about private law suits that rivals or potential rivals might file. In fact, in such a case, we would expect the DoJ to file an *Amicus Curiae* supporting the RJV and explaining why there should be no antitrust liability (Scott 2008).¹⁰

⁶ This initial effort by the NSF culminated in Link and Bauer (1989). The earliest empirical case studies on joint ventures—not necessarily research joint ventures—trace to Berg et al. (1982) and Harrigan (1985); the foundational theoretical research traces to D’Aspremont and Jacquemin (1988). The early economics literature has been reviewed by Vonortas (1997) and Hagedoorn et al. (2000); much of the subsequent management literature on this topic has been reviewed by Vonortas and Okamura (2009).

⁷ The CORE database was established and maintained at the University of North Carolina at Greensboro by Link. The CORE database is publicly available from Link for the years that it was supported by the NSF. See Link and Scott (2005) on the CORE database.

⁸ The National Science Board (2002, Chapter 4) drew explicitly on the CORE database in its discussion of U.S. research alliances.

⁹ Through 2012, there have been 1329 *Federal Register* filings, 283 of which related to activities by standards setting organizations. The NCRA of 1984 was amended again in 2004 under the Standards Development Organization Advancement Act (SDOAA), Public Law 108-237. The purpose of the SDOAA was: “To encourage the development and promulgation of voluntary consensus standards by providing relief under the antitrust laws to standards development organizations with respect to conduct engaged in for the purpose of developing voluntary consensus standards [as opposed to fundamental research]”

¹⁰ Brod and Link (2001) showed that part of the decline in filings could be explained in terms of cyclical effects in the economy.

Fig. 1. Number of RJVs in the CORE database by year of *Federal Register* filing, 1985–2012.
Source: CORE database

During the years that the CORE database was being constructed and maintained, we attempted to identify and contact the lead firm in each RJV.¹¹ It is not uncommon for a *Federal Register* filing to list a person’s name and his/her firm as the point of contact for the information in the disclosure. When a person’s name or the name of a firm does not appear in the filing, we presumed that the firm listed first among members listed in the *Federal Register* filing was the lead firm. In any event, on-going efforts were made over the past decade to establish personal contacts with all RJVs to learn about the scope of research being conducted as well as to delve into other economic and strategic matters.

In early 2014, a broad-based survey instrument was constructed and pre-tested in an effort to obtain a more in-depth understanding of RJVs.¹² Critical to this data collection effort was our ability to identify specific individuals who were in the lead firm and who were willing to participate in the survey. The decade-long effort to establish personal contacts and the two-year effort to collect survey-based information were never anticipated to result in a random sample of

¹¹ It is not uncommon for an organization, such as for example the National Center for Manufacturing Sciences, to be the lead organization in the formation of a RJV. Only RJVs with lead firms were considered in the construction of our dataset.

¹² By “broad-based,” we mean that our survey instrument addresses other characteristics of RJVs other than performance. We pre-tested our instrument in two stages. As noted above, our effort to collect information on RJVs was based on personal contacts; we did not expect to have a random sample of RJVs from the CORE database. We relied on six personal contacts who represented the lead firm in RJVs of different membership sizes to complete and offer comments for revisions on the first version of our survey instrument. There were instances where some of our personal contacts did not fully understand the question being asked, and there were also instances where our personal contacts suggested adding additional questions. Our revised survey was sent back to the pre-testers for possible final revisions. None of the six pre-testing personal contacts are included in the sample of 117.

the *Federal Register* population of 1046 RJVs or to culminate in a high response rate relative to the *Federal Register* population. Rather, it was anticipated that this effort would result in what would be the first micro-based sample of formal U.S. RJVs.

By early 2015, completed instruments were in hand from the lead firm for 117 of the 1046 RJVs noticed in the *Federal Register* in response to either the NCRA or the NCRPA. The survey dataset represents an 11% coverage ratio. The 117 RJVs included in the dataset culminates, to the best of our knowledge, the first systematic effort to collect information on a national sample of those formal RJVs that were disclosed in the *Federal Register* and chronicled in the CORE database.

Table 1 shows that the average number of members per RJV in our survey-based dataset is coincidentally comparable to the average number of members per RJV in the CORE database. The mean size of the 1046 RJVs in the CORE database is 12.93 members, and the mean size of the 117 RJVs in our dataset is 12.16 members. However, at least one very large RJV, measured in terms of membership size, in the CORE database is not in our dataset.

Table 1. Number of RJV members in the CORE database and in our survey dataset

	Mean	Standard Deviation	Range
CORE database ($n = 1046$)	12.93	32.68	2–539
Survey dataset ($n = 117$)	12.16	25.52	2–238

Note: Membership at the time of the RJV was initially noticed in the *Federal Register*

Figure 2 shows the probability density distribution of the number of RJV members for both the CORE database and our dataset. We suggest that the membership size of the RJV is an appropriate metric for comparison, especially in a study of the success of a RJV. Our argument is both conceptual and pragmatic. Conceptually, membership size proxies the resources that are available to the RJV to complete its research project; pragmatically, membership size is perhaps the most objective datum available from every *Federal Register* filing. For example, 26% of the RJVs in the CORE database at the time of the initial disclosure to DoJ had 2 members; 15% of the RJVs in our dataset had 2 members; and so forth. Visually, the two distributions are similar.

Using a two-sample test of the survey data against the CORE data, we find that the null hypothesis that the distribution of member percentages is the same cannot be rejected at even the .10 level.¹³ Thus, we suggest that our sample of 117 RJVs is representative of the population of formal U.S. RJVs disclosed in the *Federal Register* and reported in the CORE database but only in terms of membership size; therefore, generalization about U.S. RJV behavior should be made cautiously on the basis of our analysis.¹⁴

Quantifying the performance of RJVs

Two survey questions define the performance of each of the 117 RJVs.

YES or NO. Did the RJV meet or exceed all of its research goals at the time it was terminated?

If NO, approximately what percentage of the research goals were met?

Descriptive survey responses to these two survey questions are in Table 2, along with the overall ($n = 117$) percent of research goals met. Just over 27% of the RJVs met or exceeded their research goals. Of the 85 RJVs that did not meet or exceed their research goals, the mean percent of goals met is 68.3, with a range of 10 to 95%. Treating those RJVs that met or exceeded their research goals as having met 100% of their research goals, the overall performance of the sample of 117 RJVs is 77%.

Table 2. Research performance of the RJV

Performance metrics	Mean	Standard deviation	Range
Did the RJV meet or exceed all of its research goals? ($n = 117$) YES = 1; NO = 0	0.274	0.45	0/1
If NO, approximately what percent of the research goals were met? ($n = 85$)	0.683	0.176	0.10–0.95
Overall percent of the research goals that were met ($n = 117$)*	0.770	0.206	0.10–1.00

*As discussed in the text, those RJVs that reported that they met or exceeded all of their research goals were assumed, for analytical purposes, to have met 100% of their research goals

To the best of our knowledge, drawing on the extensive literature reviews by Caloghirou et al. (2003) and Vonortas and Zirulia (2015), this paper is one of a very few to quantify and analyze systematically data on the extent to which an RJV performs successfully.¹⁵ We discuss here two

¹³ This conclusion is based on a Kolmogorov–Smirnov two-sample test. $KS = 0.088989$, $D = 0.177991$, $KSa = 1.14654$, and $Pr > KSa = 0.1442$.

¹⁴ It is, however, important to emphasize that the membership size of a RJV is only one dimension by which to characterize a RJV. Other dimensions, for which we do not have *Federal Register* information, include research experience of members and research budgets.

¹⁵ There is a rich literature on the performance of firms involved in RJV activity as opposed to the performance of the RJV itself. Our focus is on the performance of the RJV itself. This literature has also recently been reviewed by Caloghirou et al. (2003) and Vonortas and Zirulia (2015).

relatively current studies that are somewhat related to venture success although neither is specific to formal RJVs.¹⁶

Zollo et al. (2002) examined survey data on collaborative research agreements among U.S. biotechnology firms. The authors created a performance index based on survey responses to Likert-scaled questions about satisfaction with the knowledge accumulated from participating in the partnership, the extent to which the partnership created new research opportunities, and the extent to which the joint research met its original objectives.¹⁷ The primary finding from this study was that previous partner-specific experience was an important driver of collaborative research success.

Others have studied dimensions of project success in research partnerships in terms of whether the cooperative project failed. For example, Lhuillery and Pfister (2009, p. 45) reported from their review of the empirical literature on cooperative arrangements that there is substantial evidence that such “agreements are inherently unstable and often produce disappointing outcomes.” With this conclusion as backdrop, the authors motivated their own analysis of R&D cooperation failure using data on formal and informal R&D partnerships from the French Community Innovation Survey. Their findings showed that failure is greater when cooperation is with foreign firms or competitors, and firms’ projects failed if they have abandoned or delayed an innovation project because of difficulties encountered in their management of inter-firm partnerships. Because Lhuillery and Pfister measured failure dichotomously, inferences about the degree of a success of a cooperative research project are problematic.¹⁸

We measure performance in two ways. We first examine if the RJV met or exceeded all of its research goals. The relevant dependent variables are *perform* and *metgoals*.¹⁹ The variable *perform* measures, for all 117 RJVs, the percent of research goals that were met.²⁰ The variable *metgoals* is a dichotomous variable equal to 1 if the RJV meet or exceed all of its research goals at the time it was terminated, and 0 if not.

¹⁶ Although not a study of RJV success, Branstetter and Sakakibara (2002) studied the level of patenting of consortia as an output indicator of success, and they found that the research budget of the consortia is a driver of such performance.

¹⁷ Relatedly, Harrigan (1986) and Gomes-Casseres (1996) viewed success objectively in terms of the venture achieving its original goals.

¹⁸ See also Lokshin et al. (2011) for a study of project failure measured in terms of project stoppages, delays, or abandonment of an RJV project.

¹⁹ Our *perform* measure is similar to Zollo et al.’s index and contains more information than the dichotomous measures used by Lhuillery and Pfister, although there is no way to determine the marginal value of that additional information. That said, our *metgoals* performance measure is also dichotomous. The origin of our performance measures traces to a workshop on collaborative research activity sponsored by the U.S. National Science Foundation (NSF) in October 2000. The workshop focused on assembling state-of-the-art thinking about strategic research partnerships. One result from the workshop was the importance of distinguishing between formal RJVs and strategic research alliances. A second result from the workshop was a charge to the NSF to add questions related to RJV activity to its annual RD-1 survey on industrial R&D. One of the suggested questions for the pilot RD-1 survey related to whether or not a firm was involved in a RJV in year *x*, and if so, what percent of the goals of the venture were realized. An overview of the papers presented at the workshop is in Jankowski et al. (2001).

²⁰ Recall from our discussion about Table 2 that we treat those RJVs that met or exceeded their research goals as having met 100% of their research goals.

We model cross-RJV differences in performance in terms of the resource base of the RJV. Our motivation for focusing on the resource base of the RJV to describe research performance comes from our view that the decision to form and/or join a RJV represents a form of what we have previously called *dynamic entrepreneurship* (Audretsch et al. 2016) or what others have called Schumpeterian innovativeness. Schumpeter defined the actions of the entrepreneur in dynamic terms as the person who innovates and who makes “new combinations” in production (1934, p. 78): “[E]veryone is an entrepreneur only when he actually ‘carries out new combinations,’ and loses that character as soon as he has built up his business, when he settles down to running it as other people run their businesses.” Schumpeter (1939, p. 62) later defined the innovative actions of the entrepreneur with more specificity in terms of a production function:

The production function] describes the way in which quantity of product varies if quantities of factors vary. If, instead of quantities of factors, we vary the form of the function, we have an innovation.

In our view, participating in a RJV represents incorporating new combinations or new resources in the pursuit of innovative actions. Thus, placing our analysis of RJV performance within the context of dynamic entrepreneurship not only allows us to motivate our focus on covariates with performance but also adds to the dynamic entrepreneurship literature by expanding our perception of the R&D-to-innovation relationship. As Audretsch et al. (2016, p. 608) emphasize:

Dynamic entrepreneurship ... refers to the action taken given that a strategically-determined opportunity has been perceived. The action being undertaken is conditional upon a decision that has already been made to exploit an opportunity.

We are viewing RJV performance as the result of action taken.

Following the terminology above, we measure the resource base of the RJV in several ways based on data available from our survey. We control for the size of the RJV, *size*, where size is measured in terms of the number of members in the RJV at the time of it being noticed in the *Federal Register*. On the one hand, the more members in a RJV the more resources the RJV has at its disposal. Thus, RJVs with more members should perform better. On the other hand, the more members there are in a RJV the broader might be the scope of the research, and, thus, size per se might not confer a performance advantage. In addition, problems associated with the coordination of research resources and intellectual property outputs might increase with membership size.

We also control for the character of the membership. In particular, we control dichotomously for whether a U.S. university was involved in the venture as a research partner, *univ*.²¹ Information about university membership in a RJV was available from the *Federal Register* filings. University research is more basic in nature than the applied research and development that occurs within firms. To the extent that such fundamental knowledge is important to providing a sound basis for the research of the RJV—which by its nature is toward the basic end of the spectrum (Bozeman et al. 1986; Link and Bauer 1989; Leyden and Link 2015)—those RJVs with

²¹ As shown in Table 4, 32.5% of the 117 RJVs include a university; however, only 15.3% of the 1046 RJVs in the CORE database include a university. Thus, our sample of 117 RJV overrepresents university involvement.

a university partner might perform better than those without.²² To elaborate, firms are more likely to enter into a RJV arrangement, which involves the sharing of resources and insights, if the results from the RJV do not confer a competitive advantage to any particular member. Thus, the research undertaken under a RJV arrangement is likely to be toward the basic end of the R&D spectrum. Also, having a university involved in the research will increase the likelihood that the research is successful. In fact, Hall et al. (2003) showed empirically that RJVs funded in part by the Advanced Technology Program within the U.S. Department of Commerce that included a university as a research partner were less likely to terminate early and thus would be more likely to achieve all or a larger portion of the venture's research goals.

We also control for the duration of the project meaning the time from the RJV being noticed in the *Federal Register* to the time when it terminated, *dur*. The date that a RJV is noticed in the *Federal Register* is known. The survey asked for the date of termination. The variable *dur* is the mathematical difference between these dates.²³ Because research by its nature, particularly basic research, is subject to uncertainty, the longer the period of cooperation the greater the ability of the venture to deal with and possibly overcome such uncertainty.

Those lead firms previously engaged in RJVs may learn from previous experience, *exper*, and accumulate more network contacts over time. Following others (Hayter 2013, 2015; Leyden and Link 2014; Vonortas and Zirulia 2015), larger and specific network ties provide knowledge and resources that, in turn, lead to greater research performance. The variable *exper* dichotomously measures if the lead firm has been involved in other RJVs. The survey question is:

YES or NO. Prior to forming this RJV, did your company have experience with other R&D collaborations?

Finally, we have information on the technology area to which the RJV research is directed, as reported by the lead firm and confirmed from the *Federal Register* filings when the information was reported.

The variables used in our analysis of RJV performance are defined in Table 3, the descriptive statistics on the variables are in Table 4, and the corresponding correlation matrix is in Table 5. The correlation matrix does predict well the direction of the regression results that are discussed below.

²² This hypothesis is not at odds with the empirical findings of Hall et al. (2001) that, using a small sample of RJVs funded in part by the Advanced Technology Programs (ATP) within the U.S. Department of Commerce, a reason for not including a university in a RJV is that an agreement could not be reached between members of the RJV and the university about intellectual property (IP) issues associated with resulting technologies. Thus, those ATP RJVs with a university as a research partner are more likely to be those where IP issues were successfully negotiated, and successful IP negotiations might imply a greater likelihood of research success.

²³ The date of a *Federal Register* filing is month, day, and year. When a survey response to the question about the date of termination of the RJV was only a year, *dur* is calculated as the year of termination less the year of the *Federal Register* filing. When a survey response included a month and a year, *dur* is calculated to the year and closest month.

Table 3. Definition of the variables

Variable	Definition	Source
<i>perform</i>	Percent of the research goals of the RJV that were met	Survey
<i>metgoals</i>	=1 if the RJV met or exceeded its research goals; 0 otherwise	Survey
<i>size</i>	Number of members at the time the RJV was noticed in the <i>Federal Register</i>	<i>Federal Register</i>
<i>univ</i>	=1 if a U.S. university is a member of the RJV; 0 otherwise	<i>Federal Register</i>
<i>dur</i>	Years from the RJV being noticed in the <i>Federal Register</i> to it being terminated	<i>Federal Register</i> and survey
<i>exper</i>	=1 if the lead firm had prior experience with other RJVs; 0 otherwise	Survey
<i>bio</i>	=1 if the RJV research is focused on biotechnology; 0 otherwise	<i>Federal Register</i>
<i>che</i>	=1 if the RJV research is focused on chemistry technology; 0 otherwise	<i>Federal Register</i>
<i>com</i>	=1 if the RJV research is focused on computer hardware; 0 otherwise	<i>Federal Register</i>
<i>def</i>	=1 if the RJV research is focused on defense technology; 0 otherwise	<i>Federal Register</i>
<i>enr</i>	=1 if the RJV research is focused on energy technology; 0 otherwise	<i>Federal Register</i>
<i>env</i>	=1 if the RJV research is focused on environmental technology; 0 otherwise	<i>Federal Register</i>
<i>it</i>	=1 if the RJV research is focused on information technology; 0 otherwise	<i>Federal Register</i>
<i>man</i>	=1 if the RJV research is focused on manufacturing technology; 0 otherwise	<i>Federal Register</i>
<i>mat</i>	=1 if the RJV research is focused on advanced material technology; 0 otherwise	<i>Federal Register</i>
<i>med</i>	=1 if the RJV research is focused on medical technology; 0 otherwise	<i>Federal Register</i>
<i>pho</i>	=1 if the RJV research is focused on photonics technology; 0 otherwise	<i>Federal Register</i>
<i>sof</i>	=1 if the RJV research is focused on computer software; 0 otherwise	<i>Federal Register</i>
<i>sub</i>	=1 if the RJV research is focused on subassembly and component technology; 0 otherwise	<i>Federal Register</i>
<i>tam</i>	=1 if the RJV research is focused on test and measurement technology; 0 otherwise	<i>Federal Register</i>
<i>tel</i>	=1 if the RJV research is focused on telecommunication technology; 0 otherwise	<i>Federal Register</i>
<i>trn</i>	=1 if the RJV research is focused on transportation technology; 0 otherwise	<i>Federal Register</i>
<i>other</i>	=1 if the RJV research is focused on a technology not listed; 0 otherwise	<i>Federal Register</i>

Table 4. Descriptive statistics on the variables ($n = 117$)

Variable	Mean	Standard deviation	Range
<i>perform</i>	0.770	0.206	0.10–1
<i>metgoals</i>	0.282	0.452	0/1
<i>size</i>	12.16	25.52	2–238
<i>univ</i>	0.325	0.470	0/1
<i>dur</i>	2.11	1.09	0.75–6.25
<i>exper</i>	0.120	0.326	0/1
<i>bio</i>	0.01	0.09	0/1
<i>che</i>	0.08	0.27	0/1
<i>com</i>	0.04	0.20	0/1
<i>def</i>	0.03	0.16	0/1
<i>enr</i>	0.09	0.28	0/1
<i>env</i>	0.10	0.31	0/1
<i>it</i>	0.04	0.20	0/1
<i>man</i>	0.14	0.35	0/1
<i>mat</i>	0.03	0.18	0/1
<i>med</i>	0.01	0.09	0/1
<i>pho</i>	0.03	0.16	0/1
<i>sof</i>	0.08	0.27	0/1
<i>sub</i>	0.07	0.25	0/1
<i>tam</i>	0.09	0.29	0/1
<i>tel</i>	0.07	0.25	0/1

Variable	Mean	Standard deviation	Range
<i>trn</i>	0.07	0.25	0/1
<i>other</i>	0.03	0.18	0/1

Table 5. Correlation matrix for the variables ($n = 117$)

	<i>perform</i>	<i>metgoals</i>	<i>size</i>	<i>univ</i>	<i>dur</i>	<i>exper</i>
<i>perform</i>	1.0					
<i>metgoals</i>	0.696***	1.0				
<i>size</i>	0.196**	0.220**	1.0			
<i>univ</i>	0.417***	0.539***	0.307***	1.0		
<i>dur</i>	0.306***	0.119	0.072	0.009	1.0	
<i>exper</i>	0.224**	0.354***	0.345***	0.138	0.072	1.0

Significant at the .05 level; *significant at the .01 level

Empirical findings

The regression results corresponding to the performance models described above are in Table 6. A generalized linear model with a probit link and binomial distribution was used when performance was measured as *perform* because the variable is bounded below by 0 and above by 1. A probit specification was used when performance was measured as *metgoals* because of its dichotomous construction. For each dependent variable, three models were considered. The first model includes *size*, *univ*, *dur*, and *exper*, and a set of indicator variables for the technology area of the RJV. Because of small cell sizes for some of the technology area indicators, we collapsed all areas representing fewer than 5 RJVs into a single category. These technology areas are as follows: *bio*, *def*, *mat*, *med*, *pho*, and *other* (see Table 3 for definitions). We also combined the *com* area with the *tel* area because the *com* area represented only 5 RJVs. Although the set of technology area indicators was jointly significant in all *metgoals* models, none of the individual categories was significantly different from the omitted category (*che*) at the .05 level, and the set was jointly insignificant in all *perform* models. Therefore, we do not report individual coefficients for these variables.²⁴

The second model incorporates the assumption that there would be diminishing returns to the impact of resources on performance. Thus, the second model includes the same set of controls as the first model plus a nonlinear impact of duration (dur^2). We also estimated this model with $size^2$, but the regression term was not significant, so we do not report the results.²⁵ For our third model, we added an interaction between size and duration ($dur \times size$) to the second model. Our reasoning for exploring this interaction term is to allow differential effects of additional resources over the period of cooperation. For example, larger RJVs may initially have an advantage over smaller RJVs due to greater resources. As time progresses, however, coordination problems in larger RJVs may manifest causing the duration slope to vary for larger RJVs compared to smaller RJVs. Also, from a purely practical standpoint, *dur* and *size* are the only continuous variables in the model, and, so, we wanted to allow a flexible functional form for those two variables rather than impose potentially binding functional form assumptions.²⁶

²⁴ These results are available from the authors on request.

²⁵ These results are available from the authors on request.

²⁶ To this end, we also estimated additional interaction terms between polynomials in *size* and *dur*, including *dur* interacted with $size^2$, *size* interacted with dur^2 , and $size^2$ interacted with dur^2 . None of the additional

Table 6. RJV performance model results ($n = 117$)

	<i>perform</i> (GLM)			<i>metgoals</i> (probit)		
	1	2	3	1	2	3
Estimated coefficients						
<i>size</i>	0.00225 (0.00375)	0.00221 (0.00418)	0.0140 (0.0110)	−0.00287 (0.00509)	−0.00364 (0.00601)	0.00834 (0.0203)
<i>univ</i>	0.725*** (0.175)	0.787*** (0.172)	0.781*** (0.172)	2.258*** (0.417)	2.649*** (0.518)	2.662*** (0.498)
<i>exper</i>	0.449* (0.237)	0.461** (0.210)	0.462** (0.218)	1.770*** (0.492)	1.779*** (0.465)	1.812*** (0.486)
<i>dur</i>	0.205*** (0.0692)	0.709*** (0.173)	0.748*** (0.172)	0.109 (0.146)	1.853** (0.783)	1.968*** (0.752)
<i>dur</i> ²		−0.0945*** (0.0263)	−0.0912*** (0.0265)		−0.336** (0.152)	−0.338** (0.152)
<i>dur</i> × <i>size</i>			−0.00481 (0.00367)			−0.00496 (0.00749)
<i>Intercept</i>	0.235 (0.231)	−0.370 (0.303)	−0.476 (0.305)	−1.265** (0.570)	−3.374*** (1.098)	−3.620*** (1.044)
0.5						
Average marginal effects						
<i>size</i>	0.000620 (0.00104)	0.000604 (0.00114)	0.00127 (0.00131)	−0.000536 (0.000948)	−0.000636 (0.00104)	−0.000432 (0.00114)
<i>univ</i>	0.181*** (0.0365)	0.192*** (0.0347)	0.191*** (0.0347)	0.547*** (0.0838)	0.592*** (0.0732)	0.589*** (0.0738)
<i>exper</i>	0.109** (0.0483)	0.110*** (0.0422)	0.110** (0.0433)	0.413*** (0.112)	0.393*** (0.100)	0.398*** (0.105)
<i>dur</i>	0.0566*** (0.0189)	0.0936*** (0.0237)	0.0960*** (0.0231)	0.0203 (0.0274)	0.0710** (0.0292)	0.0731*** (0.0279)

Heteroskedastic robust standard errors in parentheses

All models include indicators for the technology area of the RJV

*Significant at the .10 level; **significant at the .05 level; ***significant at the .01 level

The correlation coefficients in Table 5 suggest that collinearity between *size* and *univ* and between *size* and *exper* might have an interpretative impact on our findings. To investigate this issue, we estimated variance inflation factors (VIFs) for the model 1 specification for both *perform* and *metgoals*. VIFs above 10 may be indicative of multicollinearity problems, although some recommend using VIFs above 30 as the cutoff. Estimated VIFs for *size*, *exper*, and *univ* were all less than 1.5, suggesting multicollinearity is not a likely source of bias in our estimates.²⁷

coefficients were statistically significant, and the inclusion of the additional coefficients created severe collinearity problems as revealed by variance inflation factors estimated from OLS models using the same specifications.

²⁷ In addition to VIFs, we also re-estimated model 1 for *perform* and for *metgoals* deleting *size* and found our results were essentially unchanged. We also experimented with deleting *univ* and *exper*. Deleting one or the other variable had minimal impact on our results. Deleting both made the coefficient on *size* marginally significant, but not more so than *univ* or *exper* in our original results. Taken as a whole, we interpret our results to imply that *size* suffers from omitted variables bias when both *univ* and *exper* are omitted from the model, and that multicollinearity is not an issue in our analyses. These results are available from the authors upon request.

In general, our arguments for the directional relationship between *univ*, *dur*, and *exper* and RJV success are validated by our empirical analysis. We did suggest that the effect of RJV size, *size*, on RJV performance was ambiguous, and that effect is not significant in any model.

With regard to performance measured as *perform*, *size* is not statistically significant in any model, nor does it have any economic significance, as its average marginal effect is negligible. The inclusion of a university partner, however, is highly significant in all models. Based on the average marginal effect,²⁸ the percent of goals met increases by 18 to 19 percentage points when a university partner is included in the venture.

Having an experienced lead firm is significantly associated with a greater percentage of goals being met. The effect of having an experienced lead firm is slightly more than half that of having a university partner, with a marginal effect of approximately 11 percentage points. While our research propositions are stated in terms of directional relationships and not in terms of relative magnitudes of effect, the relative magnitudes of experience and university involvement on the percent of goals met (and on if goals were met, as discussed below) have, we think, an intuitive explanation. Experience is a measure of human capital, but we do not know from our data the relationship between involvement in previous RJVs and the success of the previous RJVs, and we do not know how that experience might be related to the current RJV project. Experience does reflect the ability to organize and coordinate resources, which is important but not likely to be as important as the resources themselves on research success. University involvement complements the basic research nature of the RJV's activities, and thus it has a direct and focused impact on the project. Also, university involvement might allow the venture to evaluate its research goals early-on and thereby facilitate the direction of the research to adjust or change, if needed.

Longer duration projects have a greater percentage of goals met, as evidenced by the positive and significant linear effect of *dur* on *perform*. Duration has a decreasing marginal effect, however, as shown by the significant and negative squared term. The partial effect of *dur* is also somewhat mitigated by increasing the size of the RJV as shown by the negative, although statistically insignificant, interaction of *dur* and *size*. Across all models, the marginal effect of duration remains large and significant and implies that increasing the duration of an RJV by one additional year is associated with an average increase in the percent of goals met by the RJV of nearly 10 percentage points if the non-linear relationship is accounted for.

With regard to performance measured as *metgoals*, results are qualitatively similar to those for *perform*. Having a university partner, having an experienced lead firm, and the duration of the RJV are statistically significant and positive. The marginal effect for *univ* is very large, nearly a 60-percentage point increase in the probability of meeting or exceeding all goals. When compared to marginal effect found in *perform* models, our results suggest that in many cases the 20-percentage point increase associated with the presence of a university partner is sufficient to cause the RJV to meet or exceed all of its goals. Having an experienced lead firm also has a large marginal impact on the likelihood of success, with an average marginal effect of approximately 40 percentage points.

²⁸ Marginal effects for discrete covariates are calculated as the change in the outcome associated with the discrete change in the covariate.

The results for the effect of the duration of the RJV on the likelihood of meeting or exceeding all goals highlight the importance of considering the non-linear relationship between duration and RJV performance. The linear term in model 1 is positive but small and statistically insignificant. In the quadratic models, however, the linear term is large, positive, and statistically significant. As in the models for *perform*, the squared duration term is negative and significant. The interaction of *dur* and *size* is negative but statistically insignificant. The estimated marginal effects highlight the potential economic importance of *dur*, suggesting that a one-year increase in the duration of the RJV increases the probability of the RJV meeting all of its goals by more than 7 percentage points (models 2 and 3).

Concluding remarks

Being what we believe is the first systematic descriptive study of the performance of a sample of U.S. RJVs, our findings should be interpreted with caution. However, our findings might motivate additional research in four broad areas.

The first area of additional research relates broadly to the relationship between RJV activity and dynamic entrepreneurship or Schumpeterian innovation. Much has been written about the relationship between R&D activity and innovation, but future research might consider broadening the view of R&D to include RJV activity as well as informal alliances, especially alliances with universities.

The second area of additional research, with richer data, might focus on a more complete modeling of the experience base of RJV members, not just the experience base of the lead firm. The correlation matrix in Table 5 (*size* versus *exper*) suggests that the overall experience base of an RJV might even increase exponentially with membership size, an issue prohibited by the scope of our data.

The third area of additional research is on the specifics of the research role of universities as partners in RJVs as opposed to simply the presence of a university being statistically relevant.²⁹ In addition, a more disaggregated analysis of the role of universities might shed more light on how universities promulgate greater RJV success. Still, our findings about the role of universities on RJV success are sufficient to warrant a related policy discussion about how to leverage the effectiveness of firm R&D.

Regarding universities, the results in Table 6 show that the presence of a university as a research partner has both a statistical and an economic impact on the success of a RJV. From a policy perspective, the NCRA's and NCRPA's purposes were to facilitate the formation of RJVs not to increase the successfulness of cooperative research efforts or even the level of industrial R&D. Thus, there is not a policy lever within those initiatives to pull to encourage RJVs to include a university as a research member. But, perhaps there is another lever to pull.

²⁹ For a review of the extant literature on universities as research partners, see Leyden and Link (2013) and Link (2015).

There is a rich literature that shows that firm investments in basic research have a greater impact on stimulating productivity growth than do firm investments in either applied research or development (Mansfield 1980; Link 1981; Griliches 1986; Hall et al. 2014). With that empirical fact as background, recall the R&E tax credit portion of the Economic Recovery Tax Act (ERTA) of 1981 that established a marginal tax credit for a firm's increase in R&E spending in an effort to stimulate additional spending and subsequent innovation and thus to have an impact in ameliorating the productivity slowdown.³⁰ The R&E tax credit was designed to increase a firm's total obligations to research rather than to redistribute their research toward basic. However, if policy makers were to consider a tax credit for engaging in cooperative R&D that includes a university as a research partner, observable through *Federal Register* filings, not only would investments in basic research increase, by the per se nature of collaboration, but so would the technical success of the venture and hence the effectiveness of the research.³¹

Lastly, our empirical findings show that the size of the RJV is not a statistically significant covariate with RJV performance, although the estimated coefficients in the regression models are positive possibly suggesting the effect might have economic significance. Very little evidence exists on the effect of size on the technology-based performance of the firm.³² Perhaps our results will initiate additional research that compares technology-based performance in small versus large firms.

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³⁰ The investment category of research and experimentation (R&E) is narrower than the category of research and development (R&D). For definitions, see Morris (2005). For a discussion of the R&E tax credit within the context of U.S. technology policies in response to the productivity slowdown, see Link and Link (2009) and Leyden and Link (2015).

³¹ See Bozeman and Link (1985) for details of an argument for a tax credit for cooperative research.

³² One exception is Link (1980).

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