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Multiproject contact in research joint ventures: evidence and theory

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Abstract

In the first part of this paper, we conduct an empirical analysis of all research joint ventures registered under the National Cooperative Research Act. We document the pervasiveness of multiproject contact, defined as groups of firms engaging in several research joint ventures together. In the second part of the paper, we develop a theoretical model providing a new rationale for multiproject contact. In the model, each project involves decisions that are the subject of negotiations among participants. The inefficiency associated with bargaining under asymmetric information can be mitigated if negotiations over several projects are combined.

JEL classification: C78; O32; L15

Keywords: Research joint ventures; Multiproject contact; Multimarket contact; Bargaining

1. Introduction

The National Cooperative Research Act (NCRA) of 1984 affords certain antitrust exemptions to research joint ventures (RJVs), where an RJV is defined as an organization jointly controlled by at least two participating entities whose primary purpose is to engage

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in research and development.[1] Under the terms of the NCRA, a notice is filed with the U.S. Department of Justice disclosing the RJV's principal research content and the identity of member firms. For RJVs registered in this manner, courts are required to use a rule of reason rather than a per se rule to judge antitrust violations, and liability for violations is limited to actual rather than the usual treble damages.

We analyze the prevalence of multiproject contact in a data set consisting of all the RJVs registered under the NCRA from 1985 to 1998. We show that three-quarters of these RJVs involved at least one pair of firms that also collaborated in another RJV in the sample. The extent of multiproject contact for certain pairs of firms was intense: 44 distinct pairs each collaborated in 30 or more NCRA RJVs, with one pair, Amoco and Chevron, engaging in 65 projects together.

Motivated by the empirical finding of prevalent multiproject contact in the first part of the paper, in the second part we offer a new theoretical rationale for the prevalence of multiproject contact, namely that multiproject contact may facilitate efficient bargaining among the parties. In the model, the operation of an RJV requires certain decisions to be made, and participants may disagree on the appropriate decision. The conflict of interest may come from the effect of the decision on participants' activities outside of the RJV. For example, suppose two firms have existing products arrayed on opposite ends of a product spectrum. Suppose further they form an RJV which produces a new good; each firm prefers to have the new good placed close to its existing product (and perforce far from the other firms') if the new good is a complement for its existing product and the opposite if the new good is a substitute. Participants resolve their differences through bargaining. Bargaining is generally inefficient in the presence of asymmetric information. In this paper, we investigate whether bargaining inefficiencies can be mitigated if participants bargain over several projects jointly (as multiproject contact allows) instead of each separately.

We consider a particularly simple form of bargaining under asymmetric information, allowing one party to issue take-it-or-leave-it offers to the other. Even with this simple form of bargaining, closed-form solutions are not generally available, so we resort to simulations. Our welfare function is the sum of the surplus of firms participating in the RJV, called venture surplus. We find that in nearly all cases, venture surplus is higher in the presence of multiproject contact than in the absence. The venture surplus gains can be quite large, 10 percent or more in some cases. The gains are larger when the private information of the party receiving offers is more negatively correlated across projects, but gains are sometimes realized even when there is positive correlation.

Combining bargains over multiple projects together serves to pool the random variables that are the source of asymmetric information in the model. As long as there is not perfect positive correlation between these random variables, pooling them reduces parties' private information. Private information is a friction in the bargaining process, so its reduction typically increases the probability of successful bargaining.

The rationale for multiproject contact that we offer in the theoretical section complements other explanations, pro- and anticompetitive, that might be offered: (a) certain pairs

[1] The voluminous literature on RJVs includes Katz (1986), Contractor and Lorange (1988), De Bont et al. (1992), Kamien et al. (1992), Suzumura (1992), Teece (1992), Dodgson (1993), Martin (1994), Simpson and Vonortas (1994), Coombs et al. (1996), Link (1996). See Vonortas (1997) for a survey.

of firms may have synergies that simply allow them to work well together in RJVs; (b) working together in one RJV may result in discoveries that in turn lead to follow-on projects; or (c) participating in several markets together may facilitate collusion by allowing firms to punish deviations from collusion on one market with price wars on all markets on which they meet. This last, anticompetitive explanation seems to be the dominant view in the literature (see, e.g., Scott, 1993; van Wegberg and van Witteloostuijn, 1995; Vonortas, 2000). The rationale we offer in the present paper is quite general since it follows from the fundamental nature of the bargaining process itself. Our rationale may have procompetitive implications if the negotiations facilitated by multiproject contact concern cost-reducing innovations, new products, or other actions that might increase consumer and social surplus. On the other hand, it may have anticompetitive implications if the negotiations facilitated by multiproject contact concern an action that might reduce consumer and social surplus such as restricting output or abandoning a competing technology. Collusive effects would be greatest for multiproject contact involving firms in the same industry. We find that about 44 percent of RJVs in our sample (or about 60 percent of the subset of RJVs exhibiting multiproject contact) shared a pair of firms operating in the same industry with another RJV. This finding suggests the potential for anticompetitive effects to be a concern, yet a substantial fraction of the multiproject contact involved firms in different industries, suggesting collusion was not the sole driver of multiproject contact in our sample.

The paper has the following structure. Section 2 documents the prevalence of multiproject contact among large companies in the set of RJVs registered under the NCRA. Section 3 provides a model in which multiproject contact is viewed as a way to bundle negotiations among RJV participants. Section 4 reports the results of simulations to determine the conditions under which multiproject contact is beneficial for RJV participants. Section 5 proposes a test of our theory, focusing on the implication that asymmetric information may lead RJVs to be increasingly inefficient when they have more members, so the distribution of RJVs should be skewed toward those with few members. Section 6 discusses the connections between our paper and various literatures including multi-issue bargaining, multimarket contact, organizational trust and collaboration, and bundling by a multiproduct monopolist. Section 7 concludes.

2. Evidence on multiproject contact

In this section, we study the set of all RJVs registered under the NCRA between 1985 and 1998. Using this sample, we document the prevalence of multiproject contact among participating firms. Although our sample is the universe of registered RJVs, it only represents a fraction of all RJVs in the U.S. since many go unregistered. Therefore, our findings on the *level* of multiproject contact vastly underestimates the actual level in the U.S. Our evidence on the *rate* of multiproject contact is indicative of the actual rate to the extent that registered RJVs are representative of all RJVs. Our finding of a substantial and statistically significant amount of multiproject contact in this section will motivate our search for a general rationale for multiproject contact in Section 3 and subsequent sections.

2.1. NCRA-RJV database

Maintained at the George Washington University Center for International Science and Technology Policy, the NCRA-RJV database contains information on all RJVs that have registered with the Department of Justice under the auspices of NCRA and its sequel, the National Cooperative Research Production Act of 1993 (NCRPA). The database includes longitudinal performance information on several thousands of the identified companies. Both U.S. and foreign organizations (including firms, universities, and government agencies and laboratories) have participated in NCRA-RJVs. We will use the term *entity* to denote an independent organization and *membership* to define an instance of an entity's participation in a given RJV. An entity may have more than one membership since it may be a member of different RJVs. Between 1 January 1985 and 31 December 1998, 746 new RJVs were registered. As shown in the last row of Table 1, the number of new registrations increased steadily until 1995 and steadily decreased thereafter.

Table 1 classifies RJVs by primary technical areas. Nearly all the RJVs involved high-technology areas: only 2 percent were classified as relatively low tech ("Other" in the table). Telecommunications accounted for the most RJVs (approximately 20 percent), followed by transportation, environment, energy, advanced materials, software and chemicals. Relatively little activity was recorded in areas with well-enforced intellectual property rights (biotechnology, medical equipment, pharmaceuticals).[2]

The distribution of memberships per entity, presented in Table 2, is highly skewed. Two-thirds of all identified entities have participated in only one RJV. Entities with five or more memberships account for only 9 percent of total entities but more than half (51 percent) of all memberships. The entities with the most memberships are listed in Table 3; these tend to be large publicly held corporations. Fig. 1 presents the distribution of memberships per RJV.[3] About half have fewer than five members, and half have five or more.[4]

Most U.S.-based entities (87 percent of a total of 2677 entities) were business firms. About half of them are privately held firms, about 43 percent are publicly traded firms, and about 2 percent are joint ventures and partnerships. The remaining firms are "unclassified" in terms of ownership; most are likely privately held.

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[2] Other forms of inter-firm alliances predominate in these sectors: licensing, technology swaps, marketing agreements, and mergers and acquisitions. Moreover, RJVs in these sectors often involve the collaboration of a large with a small firm, running little risk of antitrust prosecution and little benefit from NCRA registration.

[3] Fig. 1 shows that four RJVs had only one member. In three of them, the single member is itself a joint venture. Two of these three involve the 10 members of the Motor Vehicle Manufacturers Association of the United States, and one involves the long list of member financial institutions in VISA International. The fourth RJV was initially announced as open to participation, but there were no subsequent announcements of joining members.

[4] The number of RJVs with only two members is in some sense inflated by the presence of Bellcore, which is shown in Table 3 to be one of the most active entities in the database. Bellcore, the research arm of the seven regional Bell companies for most of the examined time period, was a joint venture itself. The majority of the 126 RJVs involving Bellcore have reported only one other partner and are included in the two-member category in Fig. 1. If Bellcore is broken up into its parents, the number of RJVs with more than five members increases to 68 percent of the total.

Table 1
Primary technical areas of RJVs

Technical area	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1985–1998	Percent of total
Telecommunications	8	1	6	8	10	15	17	17	23	15	11	7	7	2	147	19.7
Transportation	8	3	2	0	0	1	4	3	5	9	9	20	6	2	72	9.7
Environmental	9	1	3	2	0	6	9	3	5	6	12	8	1	2	67	9.0
Energy	5	1	2	1	4	6	9	14	7	0	1	9	6	1	66	8.8
Advanced materials	3	5	3	4	5	2	2	5	6	5	13	7	0	4	64	8.6
Computer software	1	0	1	2	4	2	3	1	4	3	18	9	7	2	57	7.6
Chemicals	2	2	2	2	7	5	8	4	1	3	2	1	3	2	44	5.9
Subassemblies and components	5	0	1	2	0	1	1	1	3	6	7	10	3	2	42	5.6
Manufacturing equipment	1	2	2	1	2	3	1	1	1	3	9	4	0	2	32	4.3
Factory automation	2	0	1	3	1	2	0	5	3	3	2	4	2	2	30	4.0
Test and measurement	0	1	1	2	1	0	4	4	1	1	6	7	0	1	29	3.9
Photonics	1	0	1	0	0	2	1	2	3	2	9	3	2	2	28	3.8
Computer hardware	1	0	0	1	0	0	1	1	4	1	4	4	0	3	20	2.7
Medicals	1	0	0	0	0	1	0	0	2	3	3	2	1	1	14	1.9
Biotechnology	1	0	0	3	0	1	0	0	1	1	3	1	0	1	12	1.6
Pharmaceuticals	1	0	0	0	0	0	0	0	1	0	1	0	1	0	4	0.5
Other	1	1	0	1	0	0	0	0	1	2	5	0	5	2	18	2.4
Column total	50	17	25	32	34	47	60	61	71	63	115	96	44	31	746	100.0

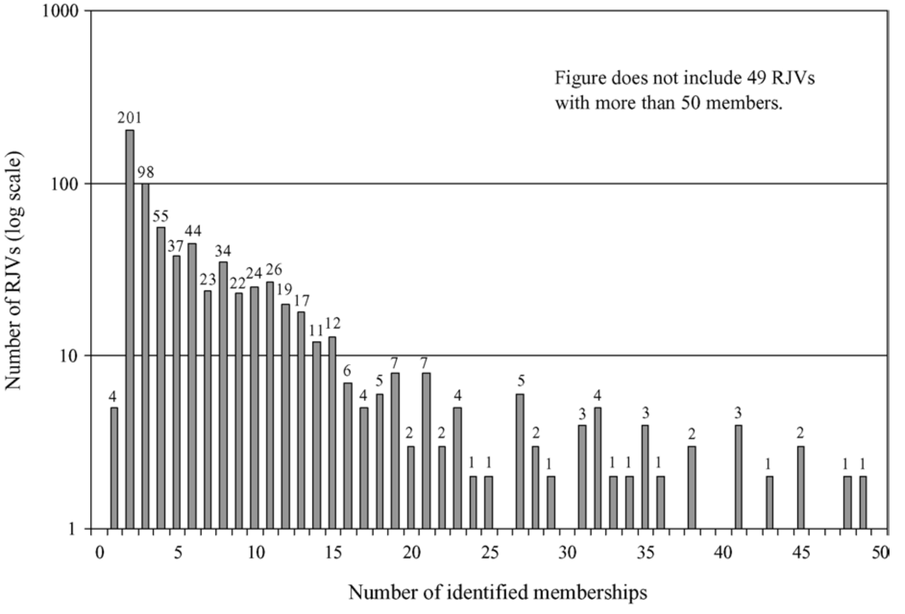

Fig. 1. Distribution of memberships per RJV.

Table 2
Distribution of memberships per entity

Memberships per entity	Entities	Percent of total	Memberships	Percent of total
1	2495	65.3	2495	24.6
2	626	16.4	1252	12.3
3	249	6.5	747	7.4
4	113	3.0	452	4.5
5	61	1.6	305	3.0
6–10	137	3.6	1069	10.5
11–20	84	2.2	1180	11.6
21–50	38	1.0	1234	12.2
More than 50	17	0.4	1416	14.0
Column total	3820	100.0	10150	100.0

Note: Of the 12,622 total memberships in the NCRA-RJV database, 10,150 could be identified. Entries in the table are for identified memberships and entities only.

2.2. Measures of multiproject contact

All pairs of collaborating entities (dyads) were listed and ranked by the number of times the same dyads appeared in different RJVs. Table 4 presents the dyads that met in 35 or more RJVs between 1985 and 1998, together with the Standard Industrial Classification (SIC) code for each entity's primary industry.[5] Twenty-eight dyads are shown to have engaged

[5] In these and other calculations, the joint ventures that have participated in NCRA-RJVs as members (Bellcore, for example) were treated as single entities. This was necessary in order to isolate the multiproject contact induced

Table 3
Entities engaged in the most RJVs

Rank	Entity	Type	Country	Memberships
1	General Motors	Publicly traded	U.S.	141
2	Bellcore	Joint venture	U.S.	126
3	AT&T	Publicly traded	U.S.	102
4	Chevron	Publicly traded	U.S.	99
5	IBM	Publicly traded	U.S.	96
6	Amoco	Publicly traded	U.S.	95
7	Exxon	Publicly traded	U.S.	92
8	DuPont	Publicly traded	U.S.	87
9	Mobil	Publicly traded	U.S.	80
10	Texaco	Publicly traded	U.S.	80
11	Hewlett-Packard	Publicly traded	U.S.	65
12	British Petroleum-Amoco	Publicly traded	U.K.	64
13	Ford	Publicly traded	U.S.	63
14	General Electric	Publicly traded	U.S.	60
15	Shell	Publicly traded	U.S.	57
16	DEC	Publicly traded	U.S.	55
17	Atlantic Richfield	Publicly traded	U.S.	54
18	Lockheed Martin	Publicly traded	U.S.	50
19	Siemens AG	Publicly traded	Germany	49
20	Motorola	Publicly traded	U.S.	47
21	Rockwell	Publicly traded	U.S.	46
22	Eastman Kodak	Publicly traded	U.S.	45
23	AlliedSignal	Publicly traded	U.S.	44
24	Phillips Petroleum	Publicly traded	U.S.	43
25	United Technologies	Publicly traded	U.S.	43

in 35 or more different RJVs together. Amoco and Chevron exhibit the most multiproject contact, engaging in 65 NCRA-RJVs together. The dominant industry represented in the table is petroleum refining (SIC 2911) due to the 62 RJVs that include at least five firms in this industry; but chemical, computer and telecommunications firms are also represented.

To provide a more formal assessment of the prevalence of multiproject contact, we took all 746 RJVs and determined which had a group of entities that also collaborated in other RJVs at any point during the time period examined. Such RJVs were classified as exhibiting multiproject contact, others not. The results are presented in the first three columns, labeled “entire period”, of Table 5. As the first entry of the table shows, 75.2 percent of the RJVs (561 out of 746) exhibit multiproject contact in the sense of having a dyad that also appears in at least one other RJV. Reading down the first column of results shows that a decreasing, but still substantial percentage of RJVs exhibited an increasingly strong form of multiproject contact in the sense of having a dyad also appearing in increasing numbers of other RJVs. For example, 47.9 percent, or about half of the RJVs, had a dyad also appearing in at least 10 other RJVs. Reading across a row increases the stringency of the multiproject contact

by NCRA-RJVs from the multiproject contact induced by joint ventures outside the NCRA set. This means, however, that information on multiproject contact between individual members of these joint ventures and other partners in NCRA-RJVs is omitted. Thus, the multiproject contact figure reported in Table 4 must be considered a lower bound.

Table 4
Pairs of firms exhibiting the most multiproject contact

Entity 1		Entity 2		RJVs containing both
Name	SIC	Name	SIC	
Amoco	2911	Chevron	2911	65
Chevron	2911	Exxon	2911	63
Exxon	2911	Mobil	2911	62
Chevron	2911	Mobil	2911	61
Amoco	2911	Exxon	2911	58
Chevron	2911	Texaco	2911	58
Amoco	2911	Mobil	2911	57
Mobil	2911	Texaco	2911	54
Amoco	2911	Texaco	2911	52
Exxon	2911	Texaco	2911	52
British Petroleum	2911	Chevron	2911	49
Ford	3711	General Motors	3711	49
Atlantic Richfield	2911	Chevron	2911	44
Amoco	2911	Atlantic Richfield	2911	41
Amoco	2911	British Petroleum	2911	41
British Petroleum	2911	Exxon	2911	41
British Petroleum	2911	Mobil	2911	41
Atlantic Richfield	2911	Mobil	2911	40
Chevron	2911	Shell	2911	39
Amoco	2911	DuPont	2820	38
Atlantic Richfield	2911	Exxon	2911	38
AT&T	4813	IBM	3570	38
Exxon	2911	Shell	2911	38
British Petroleum	2911	Texaco	2911	37
Chevron	2911	DuPont	2820	37
Chrysler	3711	General Motors	3711	37
DEC	3570	IBM	3570	37
Hewlett-Packard	3570	IBM	3570	37

in another dimension: RJVs are required to exhibit an increasingly large group of entities also appearing together in the given number of other RJVs. For example, 51.7 percent of the RJVs, about half, had three entities (triad) that also appeared in at least one other RJV. Note that it is impossible for the 205 RJVs with fewer than three members (see Fig. 1) to exhibit triadic multiproject contact. Restricting attention to the 541 RJVs having three or more members, 71.3 percent of them have a triad also appearing in at least one other RJV. Continuing along the first row of results, 38.2 percent of the RJVs have four entities (quartets) that also appear in at least one other RJV. It can be shown that this amounts to 64.3 percent of RJVs with four or more members.

For completeness, Table 5 contains all combinations of definitions of multiproject contact.[6] For example, the table shows 18.4 percent of the RJVs have a quartet that also appears in ten or more other RJVs. Overall, the table shows that a substantial fraction of

[6] Results on groups of five or more entities are not included in the table since going beyond quartets exhausted available computing power.

Table 5
Prevalence of multiproject contact analyzed at the RJV level

Number of other RJVs, formed in same time window, sharing group	Entire period			Five-year window			Three-year window		
	Two entities (dyad)	Three entities (triad)	Four entities (quartet)	Two entities (dyad)	Three entities (triad)	Four entities (quartet)	Two entities (dyad)	Three entities (triad)	Four entities (quartet)
1 or more	75.2	51.7	38.2	68.4	45.2	33.2	65.1	43.0	31.8
2 or more	68.0	45.6	33.2	59.0	39.7	27.3	54.6	36.1	23.6
3 or more	62.2	42.2	28.4	54.3	34.0	21.8	46.5	30.0	18.4
4 or more	58.4	39.8	26.9	48.4	30.4	18.0	39.9	25.3	14.3
5 or more	56.4	37.7	24.8	43.3	26.1	17.0	36.2	21.3	12.7
⋮									
10 or more	47.9	29.8	18.4	30.6	20.4	10.9	20.4	12.9	7.2
⋮									
25 or more	31.2	22.1	9.1	11.4	4.6	1.2	0.0	0.0	0.0
⋮									
50 or more	19.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: Entries are percentage of 746 total RJVs in the sample satisfying the following criteria. The candidate RJV contains a group of entities (dyad, triad or quartet) that also appears in the number of other RJVs indicated in the row label formed in the same time window. The 5-year (respectively, 3-year) time window spans 2 years (respectively, 1 year) before through 2 years (respectively, 1 year) after the year the candidate RJV was formed. For example, a 3-year window around an RJV registered in 1990 includes the years 1989, 1990 and 1991; a 3-year window around 1998 includes 1997 and 1998 (the year after 1998 is not in our sample).

RJVs exhibit multiproject contact involving dyads or large groups of entities also appearing in a large number of other RJVs.

The rationale we will develop in Section 3 for multiproject contact involves combining negotiations over issues that arise in different RJVs together and, thus, is only relevant if RJVs operate concurrently. The NCRA does not require RJVs to notify the Department of Justice when they disband, so unfortunately we do not have data on the span of RJV operation. Still, assuming that RJVs operate for at least a few years after they are registered, we can obtain a conservative picture of which operated concurrently by considering RJVs that were registered within the same time window. The last six columns in Table 5 show the amount of multiproject contact across RJVs registered in the same time window, first a 5-year window and second a more conservative 3-year window. For example, 65.1 percent of RJVs have a dyad that also appears in one other RJV registered in the same 3-year window. The results show that much of the multiproject contact was indeed exhibited by concurrent RJVs, so the bargaining model we will develop is potentially relevant for our sample.

In Table 6, we examine whether the multiproject contact found in Table 5 involves groups of entities operating in the same industry, in which case the potential for collusion is more of a concern. While 75.2 percent of RJVs have a dyad that also appeared in at least one other RJV, 58.6 percent of these or 44.1 percent of total RJVs, had a dyad with the same SIC code for their primary lines of business. These figures may understate the horizontal overlap of the collaborating entities since conglomerates may have overlapping secondary lines of business. In sum, a substantial fraction of the multiproject contact in our data involves horizontally related entities, suggesting the potential for anticompetitive effects to be a concern, but there is a substantial fraction involving entities in different industries, suggesting that a broad range of motives beyond collusion may be driving multiproject contact across the sample.

Another way to cut the data to provide evidence on the prevalence of multiproject contact is by dyads involved in the RJVs. For example, suppose RJV 1 involves three firms, A, B and C; and RJV 2 involves three firms, B, C and D. This configuration produces six *non-distinct dyads*: AB, AC and BC from RJV 1 and BC, BD and CD from RJV 2. However, dyad BC is common to both, so there are only five *distinct dyads*. The prevalence of multiproject contact can be measured by the proportion of dyads exhibiting multiproject contact. In the example, only BC exhibits multiproject contact. Hence, we can say that 1/3 of total non-distinct dyads or 1/5 of total distinct dyads exhibit multiproject contact in the example. The virtue of using the fraction of non-distinct dyads as the preferred of the two measures is that it gives additional weight to dyads with many instances of multiproject contact.

Table 7 presents the above measures of multiproject contact for the NCRA-RJVs during 1985–1998. About 11 percent of total distinct dyads, 4 percent of distinct triads and 1.4 percent of distinct quartets exhibit multiproject contact. About 27 percent of total non-distinct dyads, 9 percent of non-distinct triads and 3 percent of non-distinct quartets exhibit multiproject contact. As a benchmark against which to compare the results of Table 7, we formed a simulated sample with random memberships. For each of the 746 RJVs in our sample, we constructed a simulated analogue with the same number of members, but with the members drawn at random from the set of 3820 entities in our sample. We repeated this simulation exercise 10 times. On average across the 10 simulations, 5.7 percent of the distinct dyads exhibited multiproject contact with a standard error of 0.2. The percent

Table 6
Prevalence of multiproject contact among entities in the same industry analyzed at the RJV level

Number of other RJVs sharing group	Two-entity group (dyad)		Three-entity group (triad)			Four-entity group (quartet)		
	No constraint	Both in same SIC	No constraint	At least two in same SIC	All three in same SIC	No constraint	At least two in same SIC	All four in same SIC
1 or more	75.2	44.1	51.7	41.7	32.0	38.2	33.2	20.8
2 or more	68.0	41.2	45.6	38.1	28.7	33.2	29.4	18.4
3 or more	62.2	37.5	42.2	34.0	26.8	28.4	25.7	16.9
4 or more	58.4	36.2	39.8	33.1	26.4	26.9	24.3	16.2
5 or more	56.4	35.5	37.7	31.8	25.7	24.8	22.7	15.7
⋮								
10 or more	47.9	32.3	29.8	27.1	23.9	18.4	18.0	12.6
⋮								
25 or more	31.2	28.6	22.1	22.1	21.6	9.1	9.1	0.8
⋮								
50 or more	19.9	14.9	0.0	0.0	0.0	0.0	0.0	0.0

Notes: Entries are percentage of 746 total RJVs in the sample satisfying the following criteria. The candidate RJV contains a group of entities (dyad, triad or quartet) that also appears together in the number of other RJVs indicated in the row label. Unlike in Table 5, there is no constraint that the RJVs be formed in the same time window, but in some columns the group of firms is not considered unless it includes the indicated number of entities that share the same SIC code for their primary industry.

Table 7
Prevalence of multiproject contact analyzed at the level of entity groups

Number of RJVs in which entities appear together	Two-entity groups (dyads)				Three-entity groups (triads)				Four-entity groups (quartets)			
	Distinct		Non-distinct		Distinct		Non-distinct		Distinct		Non-distinct	
	Number (thous.)	Percent of total	Number (thous.)	Percent of total	Number (thous.)	Percent of total	Number (thous.)	Percent of total	Number (thous.)	Percent of total	Number (thous.)	Percent of total
1	226.1	88.7	226.1	73.4	15328.8	96.0	15328.8	91.2	816753.1	98.6	816753.1	97.0
2	19.8	7.8	39.6	12.9	532.3	3.3	1064.6	6.3	10871.1	1.3	21742.2	2.6
3	4.5	1.8	13.6	4.4	73.3	0.5	219.9	1.3	805.2	0.1	2415.7	0.3
4	1.7	0.7	6.9	2.2	21.2	0.1	84.7	0.5	160.9	0.0	634.4	0.1
5	0.9	0.4	4.7	1.5	9.1	0.1	45.4	0.3	51.1	0.0	255.7	0.0
6	0.6	0.2	3.3	1.1	4.3	0.0	25.6	0.2	18.1	0.0	108.6	0.0
7	0.4	0.1	2.5	0.8	2.0	0.0	14.3	0.1	7.2	0.0	50.1	0.0
8	0.2	0.1	2.0	0.6	1.1	0.0	8.6	0.1	3.1	0.0	25.0	0.0
9	0.1	0.1	1.2	0.4	0.6	0.0	5.6	0.0	1.4	0.0	13.0	0.0
10 or more	0.5	0.2	8.3	2.7	1.2	0.0	16.2	0.1	1.8	0.0	21.1	0.0
Total	254.9	100.0	308.1	100.0	15973.9	100.0	16813.8	100.0	828673.0	100.0	842028.0	100.0

Note: Number of entity groups given in thousands.

of distinct dyads in our NCRA-RJV data exhibiting multiproject contact, 11 percent, is greater than in the random simulation at any conventional level of statistical significance. On average across the ten simulations, 11.1 percent of the non-distinct dyads exhibited multiproject contact, with a standard error of 0.2. The percent of non-distinct dyads in our NCRA-RJV data exhibiting multiproject contact, 27 percent, is again greater than in the random simulation at any conventional level. The percentage of triads or quartets exhibiting multiproject contact in the simulations was negligible. We conclude that the NCRA-RJVs in our study exhibited a substantial amount of multiproject contact, more than one would expect from random groupings at any conventional level of statistical significance.

3. Model

In this section, we construct a model providing a new theoretical rationale for the prevalence of multiproject contact observed in the previous section. Stated intuitively, the rationale is that the more RJVs in which firms participate together, the more easily they are able to reach agreements when conflicts of interest arise because any asymmetric information problems between them is less severe.

3.1. Single RJV case

Two firms, indexed by $j = A, B$, are engaged in an RJV. The RJV requires decisions to be made, for example concerning placement of the new product it generates or the technology standard under which it will operate. The governance structure of RJVs requires both firms to agree on the decision. The two firms will share common interests regarding some decisions and will have conflicting interests regarding others. Let d be the single decision variable summarizing all those decisions about which A and B have conflicting interests. Suppose d can be set anywhere in the interval $[d^L, d^H]$, where d^L is B's "bliss point" and d^H is A's, as depicted in Fig. 2. The interval $[d^L, d^H]$ can be thought of as the contract curve associated with the RJV. Let $u_j(d, \omega_j)$ be the surplus that firm j earns from the RJV as a function of the location of the decision d and firm j's private value ω_j; $u_j(d, \omega_j)$ measures surplus over and above that earned if no agreement is reached, which has been normalized to zero. To capture the existence of a conflict of interest, we assume $\partial u_A/\partial d > 0$ and $\partial u_B/\partial d < 0$ (i.e., A prefers the decision to be set closer to the right end of the interval and B to the left). To take a concrete example, one of the RJVs in our data set was formed in 1992 to develop a low-cost, automated process to analyze DNA sequences, called a genosensor, to be used in applications such as diagnosing genetic diseases, designing complex drugs, and testing forensic samples. A disagreement emerged between two of the main parties in the RJV, discussed in Vonortas (1999). Beckman Instruments, a large, well-financed company with extensive experience in marketing automated biotechnology systems, preferred to develop an advanced prototype that was fully automated and that would fit into the biotechnology platform it already sold. Genometrix, a start-up with cash flow problems, preferred to develop a less ambitious prototype that could be marketed more quickly. One can think of d as indexing the simplicity of the prototype or rapidity of its marketing, with Beckman (firm A) preferring a low value and Genometrix (firm B) preferring a high value.

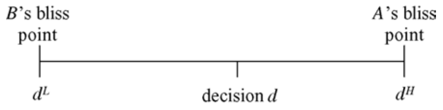

Fig. 2. Conflict of interest in RJV negotiations.

Firms' surpluses are increasing in their private values (i.e., $\partial u_j/\partial\omega_j > 0$ for $j = A, B$). Values ω_j are private in the sense of being known to firm j but not the other firm. Let $f(\omega_A, \omega_B)$ be the joint density of the firms' private values, and let $[\omega_j^L, \omega_j^H]$ be the support of ω_j. Returning to the example of the genosensor RJV from the previous paragraph, the ω_j can be thought of as including their private beliefs concerning the profit from the eventual sale of the genosensor, their private information regarding the availability of financing (venture capital, equity or other) to continue with the RJV, or their private information concerning revenue from eventual licensing of technologies developed by the individual firms (over which the firms were specified to retain property rights) outside of the RJV.

Since the governance structure of the RJV requires agreement by both firms, we must specify a bargaining process by which they arrive at decision d. We suppose that A makes a take-it-or-leave-it offer to B. This form for the bargaining process is simple and, indeed, is the most common way of modeling bargaining under asymmetric information. It would be straightforward to extend the model to allow for more even allocations of bargaining power, for example, allowing each firm an equal chance of being the one to make the take-it-or-leave-it offer, but the qualitative results would remain unchanged.[7] If B accepts A's offer, we will say that "bargaining is successful". If bargaining is successful, A earns $u_A(d, \omega_A)$ from the RJV and B earns $u_B(d, \omega_B)$; if bargaining is unsuccessful, both earn zero from the RJV.

We will place some further structure on firms' preferences for pedagogical purposes, although it should be noted that this structure is not necessary to apply the simulation methodology used in Section 4.

Assumption 1. *Firms are risk neutral.*

Assumption 2. *Let* $v(d, \omega_A, \omega_B) \equiv u_A(d, \omega_A) + u_B(d, \omega_B)$ *denote venture surplus* (*i.e., the total surplus of the RJV participants*) *if bargaining is successful. Then* $\partial v/\partial d = 0$.

The first assumption, that players are risk neutral, is a standard one when players are taken to be firms as we do. The second assumption, that venture surplus is independent of d, is natural in a setting in which firms can make lump-sum transfers during the bargaining process. If firms can make lump-sum transfers, then surplus is freely transferable between them, implying that total surplus to be divided v should not vary over the contract curve $[d^L, d^H]$. Assumption 2 allows for a simple evaluation of venture surplus: we will only need to keep track of whether bargaining is successful rather than on the exact nature of the agreement reached.

[7] Since all examples in the simulations below are symmetric, the results from Section 4 would be identical if each firm were given a random chance of making the take-it-or-leave-it offer.

The additional structure on preferences allows us to simplify the analysis considerably, as the following proposition shows. The proof of Proposition 1 is provided in Appendix A.

Proposition 1. *Under Assumptions 1 and 2, and given that A makes take-it-or-leave-it offers to B, A's surplus function can be specified as* $u_A = d$ *and B's as* $u_B = \omega_B - d$ *without loss of generality.*

In the subsequent analysis, we will adopt the functional forms $u_A = d$ and $u_B = \omega_B - d$, where $d \in [d^L, d^H]$ and where ω_B has marginal density $f_B(\omega_B)$. Proposition 1 shows these functional forms involve no loss of generality. The only caveat, discussed in the proof of the proposition, is that all resulting expressions must be understood to be implicitly conditioned on the realized value of ω_A; the functional dependence of the expressions on ω_A is suppressed for notational convenience.[8] Given these functional forms, venture surplus in the event bargaining is successful is simply ω_B.

The equilibrium offer from A to B, d^*, solves

$$\max_{d \in [d^L, d^H]} d[1 - F_B(d)]. \tag{1}$$

That is, A's expected surplus equals its surplus conditional on B's accepting the offer, $u_A = d$, times the probability B accepts, $1 - F_B(d)$, where F_B is the cumulative distribution function associated with private value ω_B. Expected venture surplus in equilibrium is

$$\int_{d^*}^{\omega_B^H} \omega_B f_B(\omega_B)\, \mathrm{d}\omega_B. \tag{2}$$

3.2. Multiple RJV case

To investigate the possible benefits of multiproject contact, we will extend the previous model to the case of two RJVs, indexed by $i = 1, 2$. Let $u_{Ai} = d_i$ be A's surplus and $u_{Bi} = \omega_{Bi} - d_i$ be B's surplus if bargaining over the decision in RJV i is successful, where $d_i \in [d_i^L, d_i^H]$ is A's offer to B and where ω_{Bi} is B's private value. Since we continue to maintain Assumptions 1 and 2, we can make these functional form assumptions without loss of generality by Proposition 1. Let v_i be venture surplus conditional on successful bargaining in RJV i: $v_i = u_{Ai} + u_{Bi} = \omega_{Bi}$, given the above functional form assumptions.

To allow for general patterns of correlation across markets, suppose private values ω_{B1} and ω_{B2} have the joint density function $f_B(\omega_{B1}, \omega_{B2})$, with marginal density functions $f_{B1}(\omega_{B1})$ and $f_{B2}(\omega_{B2})$ and correlation ρ. Zero correlation might be considered the benchmark case, but nonzero correlations arise in applications. For example, the focus of a number of the RJVs among the oil firms listed in Table 4 is on mitigating the environmental damage caused by oil production and refining. There may be a positive correlation in a firm's private benefits across these RJVs to the extent that the benefit of mitigating this damage depends

[8] For example, what we are calling the marginal density $f_B(\omega_B)$ would more precisely be the density of ω_B conditional on ω_A if ω_A were not suppressed in the notation.

in part on the scale of a firms' future operations, a constant across different methods of mitigating the damage. On the other hand, to the extent that the RJVs are pursuing substitute technologies, there might be negative correlation in private values across the RJVs: if one technology proves useful in mitigating environmental damage, there is less value in pursuing other technologies to reduce the same damage.

The analysis proceeds with a comparison of two equilibria. First, we analyze equilibrium of the game in which the firms in RJV 1 are different from those in RJV 2 so that bargaining over the decisions involved in the RJVs proceeds independently. We will refer to this as the "no multiproject contact equilibrium", *NMCE*. Second, we analyze the equilibrium in the game in which the same two firms are in both RJVs, so that bargaining over the decisions involved in the RJVs proceeds jointly. We will refer to this as the "multiproject contact equilibrium", *MCE*. Comparing the *NMCE* to the *MCE* will allow us to determine whether multiproject contact is beneficial for the RJV participants.

Analysis of the *NMCE* is particularly simple, essentially involving a two-fold repetition of the analysis from Section 3.1. Similar to (1), the equilibrium offer from A to B in RJV i, d_i^*, solves

$$\max_{d_i \in [d_i^L, d_i^H]} d_i[1 - F_{Bi}(d_i)], \tag{3}$$

where F_{Bi} is the (marginal) distribution function associated with private value ω_{Bi}. The equilibrium can be fully characterized by the pair of offers (d_1^*, d_2^*). Expected venture surplus in the *NMCE* is

$$\sum_{i=1}^{2} \left[\int_{d_i^*}^{\omega_{Bi}^H} \omega_{Bi} f_{Bi}(\omega_{Bi})\,\mathrm{d}\omega_{Bi} \right]. \tag{4}$$

Analysis of the *MCE* is complicated by the richer set of possible offers that A can make to B in this setting. In the present setting, the most general offers A can make are of the form $(d_1^S, d_2^S, d_1^J, d_2^J)$, where B can choose to have d_1^S implemented in RJV 1 and nothing in RJV 2, to have d_2^S implemented in RJV 2 and nothing in RJV 1, or to have d_1^J implemented in RJV 1 and d_2^J implemented in RJV 2. The superscript S refers to "separate" and J refers to "joint".

Let $\Omega \subseteq [\omega_{B1}^L, \omega_{B1}^H] \times [\omega_{B2}^L, \omega_{B2}^H]$ be the support of f_B. Let

$$\begin{aligned}
\Omega_1^S &\equiv \{(\omega_{B1}, \omega_{B2}) \in \Omega | \omega_{B1} - d_1^S > \max\{0, \omega_{B2} - d_2^S, \omega_{B1} + \omega_{B2} - d^J\}\},\\
\Omega_2^S &\equiv \{(\omega_{B1}, \omega_{B2}) \in \Omega | \omega_{B2} - d_2^S > \max\{0, \omega_{B1} - d_1^S, \omega_{B1} + \omega_{B2} - d^J\}\},\\
\Omega^J &\equiv \{(\omega_{B1}, \omega_{B2}) \in \Omega | \omega_{B1} + \omega_{B2} - d^J > \max\{0, \omega_{B1} - d_1^S, \omega_{B2} - d_2^S\}\}.
\end{aligned}$$

Given offer $(d_1^S, d_2^S, d_1^J, d_2^J)$ from A to B, Ω_i^S, $i = 1, 2$ is the set of private values for which B chooses d_i^S to be implemented in RJV i, and Ω^J is the set of private values for which B chooses d_1^J to be implemented in RJV 1 and d_2^J in RJV 2.

The regions are drawn schematically in Fig. 3. For $i = 1, 2$, define $\mathbf{1}_i^S$ to be the indicator function for the event $(\omega_{B1}, \omega_{B2}) \in \Omega_i^S$. Define $\mathbf{1}^J$ to be the indicator function for the event $(\omega_{B1}, \omega_{B2}) \in \Omega^J$. A's surplus, and the objective function determining the *MCE*, can then

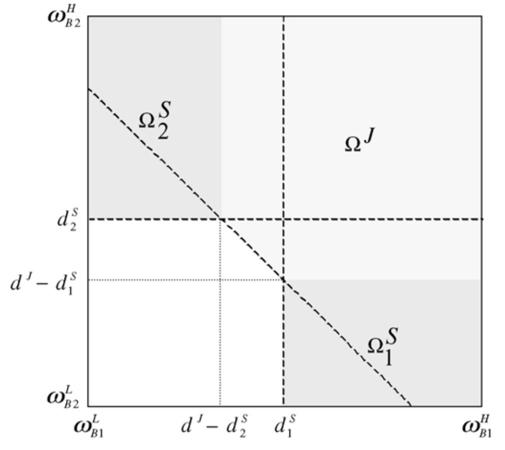

Fig. 3. Regions associated with B's acceptance of A's offers.

be written as

$$\iint\limits_{(\omega_{B1},\omega_{B2})\in\Omega} (d_1^S \mathbf{1}_1^S + d_2^S \mathbf{1}_2^S + d^J \mathbf{1}^J) f_B(\omega_{B1}, \omega_{B2})\, \mathrm{d}\omega_{B1}\, \mathrm{d}\omega_{B2}. \tag{5}$$

Let the resulting equilibrium be given by $(d_1^{S*}, d_2^{S*}, d_1^{J*}, d_2^{J*})$. Let $\mathbf{1}_i^{S*}$, $i = 1, 2$ and $\mathbf{1}^{J*}$ be the indicator functions defined above evaluated at the equilibrium decision levels. Then equilibrium venture surplus is

$$\iint\limits_{(\omega_{B1},\omega_{B2})\in\Omega} [\omega_{B1}\mathbf{1}_1^{S*} + \omega_{B2}\mathbf{1}_2^{S*} + (\omega_{B1} + \omega_{B2})\mathbf{1}^{J*}] f_B(\omega_{B1}, \omega_{B2})\, \mathrm{d}\omega_{B1}\, \mathrm{d}\omega_{B2}. \tag{6}$$

4. Simulations

4.1. Simulation methodology

For many distributions of B's private values, no closed-form solution is available for equilibrium venture surplus, (4) and (6). We therefore adopt a simulation methodology to compute (4) and (6).[9] In principle, the methodology is applicable to all densities f_B characterizing B's private values. The first step of the simulation algorithm involves taking random draws $(\omega_{B1r}, \omega_{B2r})$, $r = 1, \ldots, R$, from the distribution of B's private values. The second step involves performing a grid search over $[d_i^L, d_i^H]^4$ to find the $(d_1^{S*}, d_2^{S*}, d_1^{J*}, d_2^{J*})$

[9] There are some cases where a simulation methodology is not necessary, cases that can serve as a check on the

maximizing

$$\sum_{r=1}^{R}[d_1^S \mathbf{1}_1^S + d_2^S \mathbf{1}_2^S + (d_1^J + d_2^J)\mathbf{1}^J],$$

the simulation analogue of the double integral (5). The last step involves computing venture surplus

$$\sum_{r=1}^{R}[\omega_{B1r}\mathbf{1}_1^{S*} + \omega_{B2r}\mathbf{1}_2^{S*} + (\omega_{B1r} + \omega_{B2r})\mathbf{1}^{J*}],$$

the simulation analogue of the double integral in (6).

The methodology is especially convenient in cases in which the marginal densities, $f_{B1}(\omega_{B1})$ and $f_{B2}(\omega_{B2})$, are symmetric. In that case, there is no loss of generality in constraining $d_1^S = d_2^S$ and $d_1^J = d_2^J$, so that the grid search in the second step of the algorithm is only two-dimensional. The cases simulated below all have symmetric marginal densities.[10]

4.2. Simulation results

Table 8 presents the simulation results. The first set of simulations involves normal marginal densities with different variances and with correlations ρ varying from -0.5 to 0.5. The second set of simulations involves lognormal marginal densities with different variances and correlations. The next set involves a standard uniform marginal density with zero correlation in the private value across RJVs. The last set of simulations involves various beta marginal densities with zero correlation across RJVs.

The last column of Table 8 shows that venture surplus is higher in the *MCE* than in the *NMCE* in most cases, i.e., multiproject contact generally tends to increase venture surplus. The surplus gains can be quite large, 10 percent or more in some cases. Surplus gains are larger when ρ is lower. The only cases in which multiproject contact reduced venture surplus by a non-negligible amount involved positive correlation with the normal distributions.

Some interesting results about the mechanics of multiproject contact emerge from Table 8. In all cases, $d_i^{S*} > d_i^*$ but d_i^{J*} can be higher or lower than d_i^*. Therefore, with multiproject contact, if firm *B* accepts *A*'s offer for only one project and rejects the other, it receives worse

accuracy of the methodology. For example, suppose ω_{Bi} are independent random variables uniformly distributed on [0, 1]. Then it can be shown that (5) equals

$$2d_i^S(1-d_i^S)(d_i^J-d_i^S) + d_i^J\left[\frac{(1-d_i^J+d_i^S)^2-(2d_i^S-d_i^J)^2}{2}\right].$$

Numerically optimizing produces the values $d_i^{S*} = 0.67$, $d_i^{J*} = 0.43$ and $\sum_{i=1}^{2} u_{Ai}^* = 0.55$, nearly identical to the associated simulation values in Table 8.

[10] Among other practical considerations, we took $R = 100,000$ random draws in each case. The grid was fine enough to allow d_i^{S*} and d_i^{J*} to be estimated to two decimal places.

Table 8
Simulation results

Marginal distribution of ω_{Bi}	ρ	No multiproject contact (*NMCE*)				Multiproject contact (*MCE*)					Change in $\sum_{i=1}^{2} v_i^*$ (%)
		d_i^*	$\sum_{i=1}^{2} u_{Ai}^*$	$\sum_{i=1}^{2} u_{Bi}^*$	$\sum_{i=1}^{2} v_i^*$	d_i^{S*}	d_i^{J*}	$\sum_{i=1}^{2} u_{Ai}^*$	$\sum_{i=1}^{2} u_{Bi}^*$	$\sum_{i=1}^{2} v_i^*$	
$N(0, 0.25)$	−0.5	0.374	0.167	0.129	0.296	0.410	0.252	0.176	0.127	0.303	2.2
$N(0, 0.25)$	0.0	0.374	0.170	0.131	0.301	0.436	0.308	0.177	0.123	0.300	−0.2
$N(0, 0.25)$	0.5	0.374	0.167	0.130	0.297	0.460	0.357	0.171	0.116	0.287	−3.3
$N(0, 0.50)$	−0.5	0.512	0.236	0.191	0.427	0.580	0.341	0.250	0.182	0.431	1.1
$N(0, 0.50)$	0.0	0.512	0.241	0.193	0.434	0.593	0.423	0.251	0.183	0.434	0.0
$N(0, 0.50)$	0.5	0.512	0.236	0.192	0.428	0.621	0.481	0.242	0.176	0.419	−2.1
ln $N(0, 0.25)$	−0.5	0.770	1.083	0.840	1.923	Pure	0.807	1.379	0.681	2.061	6.9
ln $N(0, 0.25)$	0.0	0.770	1.077	0.841	1.919	Pure	0.795	1.252	0.734	1.986	3.5
ln $N(0, 0.25)$	0.5	0.771	1.803	0.839	1.922	Pure	0.777	1.165	0.793	1.958	1.8
ln $N(0, 0.50)$	−0.5	0.927	1.008	1.027	2.035	Pure	0.853	1.317	0.938	2.255	10.3
ln $N(0, 0.50)$	0.0	0.926	1.007	1.028	2.034	Pure	0.869	1.191	0.970	2.161	6.0
ln $N(0, 0.50)$	0.5	0.925	1.008	1.031	2.039	Pure	0.880	1.098	1.014	2.112	3.5
$U[0, 1]$	0.0	0.501	0.501	0.249	0.750	0.670	0.440	0.548	0.246	0.794	5.7
$\beta(1, 3)$	0.0	0.260	0.211	0.150	0.361	0.391	0.205	0.238	0.158	0.396	9.2
$\beta(1, 2)$	0.0	0.325	0.295	0.203	0.499	0.510	0.277	0.330	0.196	0.526	5.4
$\beta(2, 1)$	0.0	0.570	0.770	0.318	1.088	0.785	0.550	0.849	0.293	1.142	4.9

Notes: Notation in column headings defined in text. Last column is the percentage change in $\sum_{i=1}^{2} v_i^*$ from *NMCE* to *MCE*. "Pure" indicates that pure bundling is optimal in this case, so no price needs to be specified for single agreements. $N(\mu, \sigma)$ represents the normal distribution with mean μ and variance σ, ln $N(\mu, \sigma)$ the lognormal distribution, $U[0, 1]$ the standard uniform distribution and $\beta(a, b)$ the beta distribution with parameters a and b. Random deviates for ln $N(\mu, \sigma)$ with correlation ρ are generated by taking the exponential function of normal deviates having mean μ, variance σ and correlation ρ. Thus, the parameters μ, σ and ρ characterize the underlying normal distribution, not the resulting lognormal distribution. The actual mean for ln $N(0, 0.25)$ is about 1.1 and the variance 0.4. The actual mean for ln $N(0.0.50)$ is about 1.3 and the variance 1.1. A correlation of −0.50 (resp. 0.50) in the underlying normal deviates leads to a correlation of about −0.4 (resp. 0.4) in the corresponding lognormal distribution.

terms than it would have with separate negotiations; if firm B accepts both, the terms may be better or worse than with separate negotiations. The surplus of B, the party receiving the take-it-or-leave-it offer, is generally lower in the *MCE* than in the *NMCE*.

4.3. Intuition for simulation results

Bargaining is inefficient in the model because of the asymmetric-information problem between A and B (i.e., ω_{B1} and ω_{B2} are private information for B). Indeed, the rent B earns in expectation from its private information can be used as an index of bargaining frictions. Combining negotiations turns out to reduce B's expected information rent. Why? With separate negotiations, B is guaranteed non-negative surplus for each decision. If negotiations are combined, B need not earn positive surplus for each decision. B may accept a bundled offer d^J yielding negative surplus for one decision (say $\omega_{B1} < d^J/2$) if the surplus for the other is sufficiently positive ($\omega_{B2} \gg d^J/2$). Such cases arise with positive probability if $\rho < 1$. More formally, we have the following proposition, proved in Appendix A.

Proposition 2. *Suppose marginal densities* $f_{B1}(\omega_{B1})$ *and* $f_{B2}(\omega_{B2})$ *are symmetric, and* $\rho < 1$. *B's expected information rent is higher if A makes separate offers of d for the two decisions than if A bundles the same offers.*

The effect of decreasing B's private information rent on social surplus is similar to the effect of decreasing the elasticity of demand facing a monopolist. Suppose such elasticity is decreased by rotating the demand curve clockwise through a given equilibrium point holding price and quantity fixed. This will decrease the deadweight loss associated with monopoly. However, the monopolist may increase the price in response to the reduction in elasticity, partially offsetting the welfare gain. Our simulations show that the first effect tends to dominate, especially when private values are not too positively correlated across decisions.

5. Linking the theory and evidence

In this section, we discuss the link between the empirical evidence provided in Section 2 and the theory developed in Sections 3 and 4. We also provide additional evidence from the NCRA-RJV database that provides tentative support for our theory against alternatives.

The main motive for developing our theory was to explain the observed prevalence of multiproject contact among the RJVs in the data, so of course our theory is consistent with this fact. A number of other hypotheses are also consistent with this; indeed, any theory in which multiproject contact enhances RJVs' profitability would be. We offered three leading alternative hypotheses in Section 1. First, certain pairs of firms may have synergies that simply allow them to work well together in RJVs, a hypothesis we will label H1. Second, working together in one RJV may result in discoveries that in turn lead to follow-on projects (labeled H2). Third, participating in several markets together may facilitate collusion by allowing firms to punish deviations from collusion on one market with price wars on all markets on which they meet (labeled H3). In the remainder of the section, we will discuss evidence that can be used to sort among the alternative hypotheses.

Section 2.2 provided evidence on the collusion hypothesis, H3. H3 would have most force if the multiproject contact involved firms in the same industry. We showed that 60 percent of the RJVs exhibiting multiproject contact exhibited multiproject contact involving firms in the same industry. Collusion may be an important issue behind the multiproject contact with these RJVs. Still, the remaining RJVs exhibiting multiproject contact, a significant fraction at 40 percent, did not exhibit multiproject contact involving firms in the same industry. For these RJVs, one would need to resort to a different hypothesis (our theory, H1 or H2) for the observed multiproject contact.

Providing a rigorous empirical test separating our theory from the remaining alternatives is difficult because the differences among them are subtle. This is particularly true comparing our theory to H2. H2 roughly says the cost of generating new ideas is lower if firms already collaborate in an RJV; our theory roughly says that bargaining over decisions in one RJV is less costly if firms also collaborate in another.

One distinction between the theories is their implications for how the costs of forming an RJV vary with the number of members. H1 and H2 are silent on this question. Our theory has a definite prediction: the difficulties of bargaining under asymmetric information are multiplied as the number of members increase. To see this, consider extending the model to an RJV with N members. For simplicity, assume there is only one decision d involved, and one member (A) makes take-it-or-leave it offers to the remaining $N-1$ Bs, who have independently and identically distributed private values. If all parties must accept the offer for surplus to be generated, following the logic of Eq. (1), the proposer's offer must solve

$$\max_{d\in[d^L,d^H]} d[1-F_B(d)]^{N-1}. \tag{7}$$

The probability of successful agreement $[1-F_B(d)]^{N-1}$ shrinks exponentially with the number of members. In equilibrium, A will offer a lower value of d (i.e., more favorable to the Bs) to offset this effect, but it does not fully offset it. This can be seen in Fig. 4, which plots venture surplus as a function of the number of members, assuming the Bs' private values are independent uniform [0, 1] random variables. The picture is similar for other distributions we tried, including standard normal. In the figure, venture surplus declines in a highly nonlinear fashion. For small N, it lies above its associated logarithmic trend line. Assuming that the number of RJVs created is proportional to venture surplus, the figure suggests that there would be an "excess" of small RJVs above even a logarithmic trend line.

As Fig. 1 shows, the distribution of RJVs in our data has a similar shape. Visual inspection of the figure shows the number of RJVs with two, three and four members lie above the implicit logarithmic trend line. To show this formally, we regressed the number of RJVs with N members on the log of N, including a dummy for $N \in \{2, 3, 4\}$, using the subsample of RJVs having 50 or fewer members. The coefficient on the dummy variable was 1.38 with a standard error of 0.40, significantly different from zero at better than the 1 percent level.

The evidence on the distribution of RJVs by number of members is only suggestive. Several caveats are in order. First, while the alternative hypotheses H2 and H3 do not *require* the distribution of RJVs to look like Fig. 1 as our theory does, they are not inconsistent with this picture. There might be exogenous reasons outside of the model for the distribution

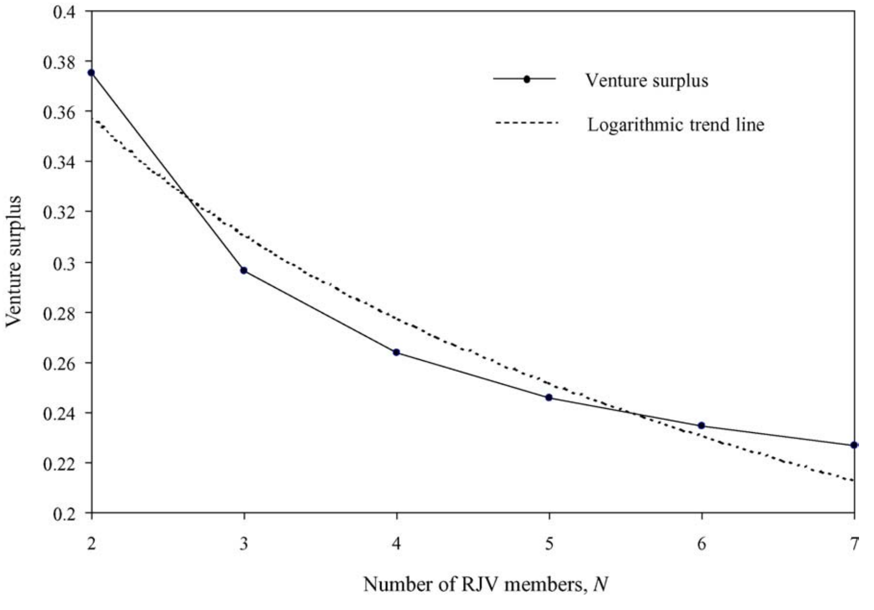

Fig. 4. Venture surplus in generalization of model with N members (i.i.d. uniform private values).

to look as it does. Second, as footnote 4 indicates, the number of RJVs with few members depends on how one regards Bellcore, the research arm of the seven regional Bell companies for most of the examined time period, a joint venture itself. It is reasonable to suppose that Bellcore bargained as a single entity, justifying our treatment of Bellcore as a single entity in Fig. 1 and elsewhere. However, if Bellcore is broken up into its parents, the number of RJVs with two, three or four members is reduced, measurably so since Bellcore was such an active RJV participant and happened to participate in RJVs with few other members. Still, the dummy variable for two, three or four members remains above the logarithmic trend line. Third, the extension of the model to N members assumed Bs' private values were not perfectly correlated. The greater the positive correlation in parties' private values, the less the efficiency of the RJV falls with the number of members.

6. Literature review

6.1. Multi-issue bargaining

An informal literature dating back to Keeney and Raiffa (1976) noted that simultaneous bargaining over multiple issues can increase efficiency relative to separate bargaining. A recent formal literature examines how moving from unrestricted (joint) bargaining over multiple issues to a restricted bargaining mechanism, such as issue-by-issue bargaining, can reduce social surplus. Much of this literature focuses on the case of perfect information between the parties (see In and Serrano, 2004 for a recent article and summary of previous papers), whereas our paper focuses on the case of asymmetric information. A series of papers (Bac and Raff, 1996; Busch and Horstmann, 1997, 1999) also consider the case of asymmetric information but in a much different setting. Asymmetric information in these papers regards discount factors rather than surplus from agreement as in our paper. These articles discuss ways that ordering or otherwise limiting the agenda can signal private information. In our paper, there is no role for signaling since the uninformed party makes take-it-or-leave-it offers.

6.2. Anticompetitive effects of multimarket contact

A theoretical literature provides a number of arguments for why multimarket contact may facilitate tacit collusion. Bernheim and Whinston (1990) show that multimarket contact may pool asymmetries across firms and markets, thereby reducing the incentive to deviate on markets most prone to deviation. Spagnolo (1999) shows that if firms' have concave utility functions over profit, multimarket contact always facilitates tacit collusion because the loss from punishment for deviation increases more than proportionately with the gain from deviating as markets are added. In Matsushima (2001), firms have imperfect ability to observe rivals' past supply decisions, making tacit collusion is difficult. Multimarket contact effectively improves firms' ability to monitor each other.

Our paper provides a mechanism for multimarket/multiproject contact to facilitate explicit collusion of the sort modeled by Cramton and Palfrey (1990). Bundling markets reduces the heterogeneity of firms' private information and makes collusive agreements more efficient. Our work provides another formal justification for Scott's (1993) idea that symmetry enhances collusion.

6.3. Strategic partnerships and business networks

The paper also contributes to the literature on strategic partnerships and business networks (e.g., Kogut, 1988; Gomes-Casseres, 1996; Gulati, 1998). This literature has emphasized that inter-organizational arrangements that build trust and reputation tend to be efficient. It is argued that such arrangements are particularly important in markets with emerging technologies and high levels of uncertainty due to the lack of a dominant technological trajectory (Kash and Rycroft, 1999). Our theory demonstrates a formal mechanism by which such efficiencies may arise: repeated collaboration in research and development allows firms to know each other better, in turn allowing them to reach agreements more easily when conflicts of interest arise. The firms know each other better in the formal sense of Proposition 2 (i.e., that their private information rent is lower).

6.4. Bundling literature

Given our formulation of bargaining under asymmetric information, our model turns out to be analogous to the McAfee et al. (1989) model of bundling by a multiproduct monopolist. Firm *A* is analogous to the multiproduct monopolist. Firm *B* is analogous to the monopolist's consumer base. The offer from *A* to *B*, $(d_1^S, d_2^S, d_1^J, d_2^J)$, is analogous to the menu of prices in a bundling contract. In particular, d_1^S and d_2^S are reinterpreted as the prices charged by the multiproduct monopolist for the separate goods, and the sum $d_1^J + d_2^J \equiv d^J$ is reinterpreted as the price the multiproduct monopolist charges for the bundle. Given these reinterpretations, expression (5) is equivalent to the objective function of a multiproduct monopolist.

Our interest lies in assessing the effect of multiproject contact on the combined surplus of all RJV participants (venture surplus) analogous to assessing the effect of bundling by a multiproduct monopolist on the combined surplus of producers and consumers (social surplus). McAfee et al. only have results on the private optimality of bundling for the monopolist, not the social optimality. Thus our analysis can also be viewed as a contribution to the bundling literature. Recall that the result from the previous section showed that multiproject contact generally tends to increase venture surplus. In the context of bundling by a multiproduct monopolist, this implies that bundling tends to increase social surplus.

A number of papers on bundling by a multiproduct monopolist prior to McAfee et al. have some results on the social optimality of bundling. Schmalensee (1982) derives results on social optimality in the context of a single-product monopolist bundling a competitively supplied good, showing that social surplus may either increase or decrease with bundling depending on the distribution of consumers' reservation values. Schmalensee (1984) considers bundling by a multiproduct monopolist under the assumption of Gaussian consumer valuations. Using both analytic and numerical techniques, he finds that the social optimality of pure bundling (constraining the monopolist to offer only the bundle and not the goods separately as well) depends on the underlying parameters. He does not analyze the social optimality of mixed bundling (allowing the monopolist to offer consumers the bundle as well as the separate goods). Mixed bundling represents the most general form of bundling and is thus the relevant form to consider for our application to RJVs. Palfrey (1983) considers mixed bundling, but in the context of an auction with several competing buyers and no reservation price for the seller. This setting is quite different from ours: viewed in terms of auctions, our setting involves one buyer and a reservation price for the seller. Palfrey finds that bundling reduces social welfare, though welfare in his setting depends on whether the high-value consumer obtains the good rather than on, as in our setting, whether trade is consummated. It is in fact Adams and Yellen's (1976) seminal article that has the most relevant results on social welfare. They construct examples in which social welfare increases, and some in which it decreases, if mixed bundling is feasible. The generality of their results is limited by their consideration of discrete types of consumers having perfectly negatively correlated values across goods. Our methodology applies to arbitrary distributions of consumer types with arbitrary patterns of correlations across goods.

7. Conclusion

This paper makes two direct contributions. First, it establishes the prevalence of multiproject contact in a large set of RJVs registered under the National Cooperative Research Act from 1985 to 1998. Over three-quarters of the RJVs exhibited multiproject contact in the sense of having a dyad that also appeared in at least one other RJV together. A substantial fraction of these RJVs exhibited even more multiproject contact than this minimal definition, with larger groups of firms than dyads appearing in many other RJVs. Over 10 percent of the distinct dyads and a quarter of the non-distinct dyads (pairs of firms participating together in RJVs) exhibited multiproject contact. This is about twice as much multiproject contact as would be expected under the null hypothesis of random collaboration, allowing us to reject the null of random collaboration at any conventional level of statistically significance.

While we do not have direct evidence on whether the observed multiproject contact was pro- or anticompetitive, we can observe whether or not it involved firms in the same industry. Collusion is more of a concern if multiproject contact involves firms in the same industry. We found that about 60 percent of RJVs exhibiting multiproject contact shared a pair of firms operating in the same industry with another RJV, and the remaining 40 percent did not. Thus collusive effects are a cause for concern, but may not drive all the multiproject contact in our sample.

Motivated by the prevalence of multiproject contact we found in the empirical part of our paper, in the theoretical section we developed a new rationale for multiproject contact. Simulations from our model of bargaining under asymmetric information indicate that, in most cases, venture surplus is higher in the presence of multiproject contact than in the absence, due to the relative efficiency of bargaining over multiple issues simultaneously instead of each separately. Bundling negotiations tends to reduce bargaining frictions by reducing parties' private information rents that are the source of bargaining frictions in the model.

The paper contributes indirectly to four other literatures. First, our paper contributes to the theoretical literature on multi-issue bargaining by suggesting that the efficiency of bargaining under asymmetric information can be improved by having parties bargain over multiple issues jointly rather than separately. Second, we contribute to the theoretical literature on facilitating collusion through multimarket contact. The literature has largely focused on tacit collusion; we show that multimarket contact may facilitate explicit collusion as well. Third, our model represents a formal contribution to the business literature on organizational trust and collaboration. Fourth, in the light of the analogy that can be drawn between our model and models of bundling by a multiproduct monopolist, our results bear on the question of the social efficiency of bundling, a question that has not yet been settled in the bundling literature. Our simulation results suggest that bundling is likely to enhance social welfare and thus, as a matter of policy, should generally not be prohibited.

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Appendix A

Proof of Proposition 1. Assumption 1 implies u_A and u_B are linear in d:

$$u_A(d, \omega_A) = \alpha_0(\omega_A) + \alpha_1(\omega_A)d, \tag{A.1}$$

$$u_B(d, \omega_B) = \beta_0(\omega_B) - \beta_1(\omega_B)d \tag{A.2}$$

for arbitrary functions $\alpha_0(\omega_A)$ and $\beta_0(\omega_B)$ and for positive functions $\alpha_1(\omega_A)$ and $\beta_1(\omega_B)$ (these functions must be positive to preserve the signs of $\partial u_j/\partial d$ that we have assumed). Assumption 2 implies $0 = \partial v/\partial d = \partial u_A/\partial d + \partial u_B/\partial d = \alpha_1(\omega_A) - \beta_1(\omega_B)$. Hence, $\alpha_1(\omega_A) = \beta_1(\omega_B) = K_1$ for some constant $K_1 > 0$, independent of the private values.

Let $\tilde{d} \equiv \alpha_0(\omega_A)+K_1 d$, $\tilde{d}^L \equiv \alpha_0(\omega_A)+K_1 d^L$, $\tilde{d}^H \equiv \alpha_0(\omega_A)+K_1 d^H$, $\tilde{\omega}_B \equiv \alpha_0(\omega_A) + \beta_0(\omega_B)$ and

$$\tilde{f}_B \equiv \frac{f_B(\beta_0^{-1}(\tilde{\omega}_B - \alpha_0(\omega_A)))}{|\beta_0'(\beta_0^{-1}(\tilde{\omega}_B - \alpha_0(\omega_A)))|},$$

where f_B is the marginal density of ω_B. Note that $\tilde{f}_B$ is the marginal density of a function of the random variable ω_B, computed according to the usual formula (see, e.g., Bickel and Doksum, 1977, formula A.8.9). Then (A.1) and (A.2) can be written equivalently as

$$\tilde{u}_A(\tilde{d}) = \tilde{d}, \tag{A.3}$$

$$\tilde{u}_B(\tilde{d}, \tilde{\omega}_B) = \tilde{\omega}_B - \tilde{d}, \tag{A.4}$$

where $\tilde{d} \in [\tilde{d}^L, \tilde{d}^H]$ and where $\tilde{\omega}_B$ is a random variable with marginal density $\tilde{f}_B$.

Eqs. (A.3) and (A.4) provide the same representation of surpluses as in the statement of the proposition except for one feature: $\tilde{d}$, $\tilde{d}^L$, $\tilde{d}^H$, $\tilde{\omega}_B$ and $\tilde{f}_B$ are all implicitly functions of ω_A here, while the statement of the proposition requires them to be independent of ω_A. Since A makes take-it-or-leave-it offers, the equilibrium level of the decision variable comes from maximization of A's objective, an objective in which ω_A is an observable so that the resulting solution is conditional on ω_A. Therefore, all relevant expressions will be conditional on ω_A, so we can suppress the dependence of all expressions (in particular $\tilde{d}$, $\tilde{d}^L$, $\tilde{d}^H$, $\tilde{\omega}_B$ and $\tilde{f}_B$) on ω_A, recognizing the implicit conditioning on ω_A. □

Proof of Proposition 2. B's expected information rent with the separate offers is

$$\begin{aligned}
&\int_{\{\omega_{B1}\geq d\}} (\omega_{B1} - d) f_B(\omega_{B1})\,\mathrm{d}\omega_{B1} + \int_{\{\omega_{B2}\geq d\}} (\omega_{B2} - d) f_B(\omega_{B2})\,\mathrm{d}\omega_{B2} \\
&= 2\int_{\{\omega_{B1}\geq d\}} (\omega_{B1} - d) f_B(\omega_{B1})\,\mathrm{d}\omega_{B1} \\
&= 2\int_{\{\omega_{B1}\geq d\}} (\omega_{B1} - d) \left[\int_{\omega_{B2}^L}^{\omega_{B2}^H} f_B(\omega_{B2}|\omega_{B1})\,\mathrm{d}\omega_{B2}\right] f_B(\omega_{B1})\,\mathrm{d}\omega_{B1}
\end{aligned}$$

$$= 2 \iint_{\{\omega_{B1} \geq d\}} (\omega_{B1} - d) f_B(\omega_{B1}, \omega_{B2})\, \mathrm{d}\omega_{B1}\, \mathrm{d}\omega_{B2}. \quad \square \tag{A.5}$$

The second term holds because the distributions of ω_{B1} and ω_{B2} are symmetric. The third term holds since the bracketed term equals one. The last term holds since $f_B(\omega_{B2}|\omega_{B1}) f_B(\omega_{B1}) = f_B(\omega_{B1}, \omega_{B2})$. B's expected information rent with the bundled offer is

$$\begin{aligned}
&\iint_{\{\omega_{B1}+\omega_{B2} \geq 2d\}} (\omega_{B1} + \omega_{B2} - 2d) f_B(\omega_{B1}, \omega_{B2})\, \mathrm{d}\omega_{B1}\, \mathrm{d}\omega_{B2} \\
&= \iint_{\{\omega_{B1}+\omega_{B2} \geq 2d\}} (\omega_{B1} - d) f_B(\omega_{B1}, \omega_{B2})\, \mathrm{d}\omega_{B1}\, \mathrm{d}\omega_{B2} \\
&\quad + \iint_{\{\omega_{B1}+\omega_{B2} \geq 2d\}} (\omega_{B2} - d) f_B(\omega_{B1}, \omega_{B2})\, \mathrm{d}\omega_{B1}\, \mathrm{d}\omega_{B2} \\
&= 2 \iint_{\omega_{B1}+\omega_{B2} \geq 2d} (\omega_{B1} - d) f_B(\omega_{B1}, \omega_{B2})\, \mathrm{d}\omega_{B1}\, \mathrm{d}\omega_{B2} \\
&< 2 \iint_{\substack{\{\omega_{B1}+\omega_{B2} \geq 2d\} \\ \{\omega_{B1} \leq d\}}} (\omega_{B1} - d) f_B(\omega_{B1}, \omega_{B2})\, \mathrm{d}\omega_{B1}\, \mathrm{d}\omega_{B2}.
\end{aligned} \tag{A.6}$$

The second term follows from simple algebraic manipulation. The third term holds by symmetry of the distributions. The last term holds since the integrand is negative for $\omega_{B1} < d$. Comparing (A.5) and (A.6), it is apparent that (A.5) is greater since the integrand is non-negative over the range of integration, and the range of integration is strictly larger in (A.5) as long as $\rho < 1$.

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