Do Research Joint Ventures Serve a Collusive Function?

Michelle S. Goeree and Eric Helland[1]

July 17, 2008

Abstract

Every year thousands of firms are engaged in research joint ventures (RJV), where all knowledge gained through R&D is shared among members. Most of the empirical literature assumes members are non-cooperative in the product market. But many RJV members are rivals leaving open the possibility that firms may form RJVs to facilitate collusion. We exploit variation in RJV formation generated by a policy change that affects the collusive benefits but not the research synergies associated with an RJV. We estimate an RJV participation equation and find the decision to join is impacted by the policy change. Our results are consistent with research joint ventures serving a collusive function.
JEL Classification: L24, L44, K21,O32
Keywords: research and development, research joint ventures, antitrust policy, collusion

---

[1] Michelle S. Goeree is at University of Southern California; Eric Helland is at Claremont McKenna College. Corresponding author is Michelle Goeree (email: michelle.goeree@gmail.com).
This research has benefited from comments of seminar participants at the DOJ Antitrust Division, Claremont McKenna, University of Melbourne, Monash University, IIOC meetings (Savannah), SEA meetings, and discussions with David Bjerk, Linda Cohen, Jonah Gelbach, Jacob Goeree, Hugo Hopenhayn, Serkan Ozbeklik, Josh Rosett, Janet Smith, and Marc Weidenmier. We gratefully acknowledge support from the Financial Economics Institute and the Lowe Institute of Political Economy. We thank Katy Femia and Elissa Gysi for excellent research assistance and Albert Link for providing the CORE data.

1 Introduction

Every year thousands of firms are engaged in research joint ventures (RJV), an agreement in which all knowledge gained through research and development (R&D) is shared among members. RJVs often provide procompetitive benefits, such as shared risk, increased economies of scale in R&D, asset complementarities, internalized R&D spillovers (i.e. overcoming free-rider problems in R&D), alleviated financial constraints, and shared cost. The majority of the literature focuses on the benefits of RJVs and assumes that members compete but do not collude in the final product market.[1] However, by construction, RJVs permit multiproject and multimarket contact and offer firms an opportunity to coordinate behavior. As Martin (1995) notes, "It is conceivable that firms that start to work very closely on R&D projects might start to extend the coordination of their behavior onto other spheres of the life of the firms."

There are numerous ways in which R&D collaborations may lead to collusive product market behavior.[2] For instance, RJV formation could centralize decision making by combining collaborative efforts with control over competitively significant assets, by imposing collateral restraints that restrict competition among participants, by including member firms' individual R&D in the collaborative effort, or by facilitating the exchange of competitively sensitive information.[3] Finally, production joint ventures, which involve jointly manufacturing a new or improved product, typically involve agreements on the output level, the price of the joint product, or other significant competitive variables.

[1] See for instance, Marin, et al (2003), Cassiman and Veuglers (2002), Kaiser (2002), Hernan, et al (2003), and Roller, et al (2007). Caloghirou and Vonortas (2000) and Hagedoorn, et al (2000) provide summaries of the RJV formation literature.

[2] Theoretical papers that address the potential for product market collusion among RJV members include d'Aspremont and Jacquemin (1988) who consider a duopoly model of R&D coordination and find that welfare is improved by R&D cooperation (when spillovers are high) but that in many cases welfare is reduced if firms collude in output. Martin (1995) finds that self-enforcing R&D makes it more likely that tacit collusion can be sustained in the product market. Greenlee and Cassiman (1999) develop a model in which RJV formation is endogenous, as is the decision to collude in the final goods market. They find that RJVs should not be supported if they involve product market collusion. Cooper and Ross (2007) present a theoretical model in which a joint venture between firms in one market can serve to facilitate collusion in another market.

[3] See Conner (2001) for a discussion of how trade association meetings have been used to mask illegal collusive activity.

This is only a potential concern if RJV members are product market competitors. In reality, research joint ventures frequently involve firms who are competitors in the final goods market. Some examples of direct product market competitors who are involved in RJVs include Xerox and Dupont who formed an RJV to develop copying equipment; General Motors and Toyota to produce a new type of car; Merck and Johnson & Johnson to develop new over the counter medicines; ABC, NBC, CBS and Cable News Network to conduct exit polls and pool information during national elections; and, perhaps the most famous, SEMATECH, a consortium of leading semiconductor manufacturers established to improve semiconductor manufacturing technology.

The possibility that firms may undertake legal RJVs as a means to facilitate illegal product market collusion has generated regulatory scrutiny and litigation in a wide variety of industries and research areas.[4] For instance, there have been a number of RJV agreements among firms in the petroleum industry that have created competitive concerns in the US in the past.[5] More recently European antitrust authorities required Mobil Corp to withdraw from a refining and marketing RJV with BP Amoco as a condition for approval of its merger with Exxon Corp. RJVs are also prevalent in the airline industry where a number of antitrust concerns over codesharing has raised collusive concerns. Indeed, a study by Oum and Park (1997) found that the 30 largest airlines were involved in over 300 various types of alliances in 1996 alone. The collusive potential of RJVs is not only a recent concern among policy makers. For instance, in the early 1980s antitrust authorities voiced concern over the cartel-inducing properties of RJVs formed in the movie industry. Specifically, major movie companies created an RJV where members would provide movies exclusively to a pay network for a limited time before making them available to other networks.[6]

To our knowledge, the question of whether collusive behavior may be facilitated by RJVs has not been addressed in the empirical literature.[7] In this paper, we attempt to fill this gap.

---

[4] For an extensive discussion see Brodley (1990), Jorde and Teece (1990), and Shapiro and Willig (1990).

[5] See Wilson (1975) for numerous examples.

[6] United States v. Columbia Pictures Indus 507 F. Supp. 412 n. 47 (S.D.N.Y 1980).

[7] The closest empirical work on this topic is that of Scott (1988, 1993), who examined all RJV filings over an 18 month period and found that collaboration may have resulted in less competitive markets. However,

Estimating the impact of the returns to collusion on the decision to join an RJV, independent from the other factors determining the decision to join the venture, is difficult. Rather than directly testing for collusion by firms engaged in RJVs we examine their potentially collusive function through a quasi-experiment.[8]

The quasi-experiment tests whether a 1993 revision of antitrust leniency policy, which was enacted to detect collusive behavior, made firms more or less likely to join research joint ventures. We argue that the 1993 revision to the leniency policy made applying for amnesty easier and more attractive and hence the leniency policy reduced the gains from trying to establish a collusive relationship because coconspirators would be more likely to defect and seek amnesty. This change in the value of collusion should change the value of joint a research joint venture only if the RJV serves some sort of collusive function at the margin. Since the leniency policy applies to all firms after 1993 we are concerned that our results might be driven by some unobserved trends in the data. For this reason we also examine whether the leniency policy revision differentially impacts firms for whom collusion might be more valuable. To do so, we present a measure of the RJV's collusive value that would result if the firm in question joins a particular RJV. Our test of RJV's collusive function is whether the revised leniency policy changes the probability that firms join an RJV and whether the policy has a differential impact on the probability a firm joins an RJV if the market power of the RJV is larger or smaller.[9]

as Reinganum (1983) notes, RJVs influence R&D levels differently for those firms in the venture relative to those not in the venture. For instance, RJVs may exaccerbate initial asymmetries across firms, resulting in increased market power for those firms in the RJV. Hence RJVs may affect market structure and market power absent collusive product market behavior.

[8] Specifically, we do not look at a subset of firms engaged in RJVs and another subset not engaged in RJVs and test whether collusion is higher among the first group. For one thing, this test would only be able to tell us something about collusive behavior that was detected and could say nothing about firms that form RJVs with collusive intentions but are not caught. What we propose is a way to test whether the data are consistent with firms forming RJVs as a way to facilitate collusion in the final goods market. Further, we cannot test for direct evidence of collusion by estimating a structural model for reasons we discuss later.

[9] We cannot predict what direction the impact of the leniency policy will be. For example it is possible that the leniency policy makes all collusive arrangements less attractive and hence RJV are less common after the policy and even less common among RJV that would have had a higher collusive value before the policy. Alternatively the legal protection afforded by the registering the RJV may make it a more attractive option following the leniency policy. While important for policy makers the exact sign of the impact of the leniency policy is not important for our test since there is no reason why the leniency policy should impact RJV formation unless some of these ventures serve a collusive purpose.

The obvious problem, which plagues the majority of studies of final market collusion, is defining the final product market. To this end we examine three definitions of the final product market: 6 digit NAICS, 3-digit NAICS, and telecommunications industry. We single out the telecom markets for a several reasons. First, the telecom sector is very important to the US economy and is a critical input in production as well as consumption. Second, RJVs among the top telecom firms are common with 38% of firms involved in at least one RJV with another direct product market rival. In addition there is a history of potentially collusive behavior among telecom firms. Finally, and most importantly for our methodological difficulties in determining final product markets, is that regulatory mandates during a portion of the sample period result in a well-defined final product market for long distance service. Specifically, between 1984 and 1996, telecom firms were not permitted to offer both local and long distance services.[10] During this period of regulation, the market for long distance services consisted of a regulated dominant firm (AT&T), two main competitors (MCI and Sprint), and hundreds of resellers. AT&T was required to provide services to all long distance customers, to file with the Federal Communications Commission (FCC) when it wished to add a new service, and to average its rates across broad consumer markets. MCI and Sprint were not regulated in their prices or provision of services. Despite being unregulated, MCI and Sprint charged prices a little lower than those of AT&T. Furthermore, almost every new rate decrease proposed by AT&T was challenged under the umbrella of predatory behavior. These observations have led some economists to classify the market for long distance services in the 1990's as collusive with AT&T as the price leader.[11] It is also notable that from 1984 to 1996, AT&T, MCI, and Sprint were involved in a number of RJVs.

For all our market definitions, we find that the decision to join an RJV is impacted by the policy change and that this impact is very significant among telecom firms. Specifically, we find that the revised leniency policy reduces the probability telecom firms join a given

[10] In 1984, AT&T relinquished its hold on the local market when the Department of Justice ordered AT&T to divest its local telephony business. These companies became the Regional Bell Operating companies or RBOCs. Local operators were not permitted to offer long distance services until the Telecommunications Act of 1996.

[11] See Huber, et al (1992) and MacAvoy (1995).

RJV by 25%. Our results are consistent with RJVs serving, at least in part, a collusive function.

The rest of the paper proceeds as follows. In section 2 we provide background on the legal policies surrounding RJV formation and collusive behavior. We present the model and estimation technique in section 3. In section 4 we discuss the data. We present the results in section 5. In section 6 we conclude.

2 Antitrust Policy Background

2.1 National Cooperative Research and Production Act

The National Cooperative Research Act (NCRA), established in 1984, requires all firms interested in forming an RJV to file with the Federal Trade Commission (FTC).[12] The NCRA was extended in 1993 to include all firms involved in production joint ventures (and was renamed the National Cooperative Research and Production Act, NCRPA). By filing, member firms are granted antitrust protection, which limits their possible antitrust exposure to actual (rather than treble) damages, plus costs and attorneys' fees with respect to activities identified in the filing.[13] In addition, antitrust authorities are required to apply the (more lenient) *rule of reason* rather than the *per se* illegality rule during prosecution.[14]

In deciding whether to approve a proposed RJV, the primary consideration of the FTC is whether the venture is likely to give member firms the ability to retard the pace or scope of R&D efforts. In practice, antitrust authorities are unlikely to challenge an RJV when there are at least three independent firms with comparable research capabilities to those of

[12] According to the National Cooperative Research Act, an RJV is defined as "any group of activities, including attempting to make, making or performing a contract, by two or more persons for the purposes 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 finding or theory of a scientific or technical nature into practical application for experimental and demonstration purposes..., (d) the collection, exchange, and analysis of research information, or (e) any combination of the [above]."

[13] Prevailing defendents are entitled to recover costs and attorneys' fees if an action is found to be "frivolous, unreasonable, without foundation, or in bad faith." See 15 USC section 4304(a)(2)(2000).

[14] If a behavior is *per se* illegal (e.g. price fixing) then authorities need only prove the behavior exists, there is no allowable defense for the accused parties. Under the *rule of reason* authorities are required to examine the inherent effect and the intent of the practice.

the proposed RJV. Furthermore, authorities have indicated they will not challenge RJVs in certain research areas. For example, authorities will permit modifications to RJVs involving pharmaceutical firms engaged in cardiovascular research; those formed by the four US manufacturers of centrifugal pumps (used by electrical utilities) that focus on improving pump reliability and performance; or RJVs formed to conduct R&D relating to computer aided design and manufacturing.[15]

The research focus of RJVs varies greatly. The majority occur in seven major research areas: telecommunications, transportation, environment, energy, advanced materials, software, and chemicals. These research areas span many North American Industrial Classification System (NAICS) industry classifications. For instance, firms involved in RJVs with a telecommunications research focus come from 19 industries ranging from petroleum manufacturing to publishing.

2.2 Leniency Policy

The Sherman Act of 1890 makes it illegal for firms to agree to fix prices or engage in other agreements that restrict output or harm consumers. In 1978, the US Department of Justice (DOJ) Antitrust Division enacted the leniency policy program designed to detect firms engaged collusive behavior. The DOJ substantially revised the leniency program, in August 1993, to make it easier and financially more attractive for firms to cooperate with the Division.[16] According to a DOJ policy statement, "Leniency means not charging such a firm criminally for the activity being reported." There were three major revisions: (i) amnesty was made automatic if there was no pre-existing investigation (ii) amnesty could be granted even if cooperation began after the investigation was underway (iii) all directors, officers, and employees of the filing firm are protected from criminal prosecution. There is

[15] See US DOJ Business Review Letter to American Heart Association March 20, 1998; US DOJ Letter to the Pump Research and Dev. Comm., 1985; and the US DOJ Letter to Computer Aided Mfg. Int'l Inc. 1985, respectively.

[16] The timing of the broadening of the NCRPA coincides with the revision of the leniency policy. Note, however, that we would expect to see more RJVs formed due to the NCRPA broadened protection. If the effect of the leniency policy is to reduce RJV applications, the presence of the NCRA revision would make any negative significant results we find even stronger.

one important caveat: only the first company to file receives amnesty.[17]

In addition to making it more attractive for cartel members to report illegal behavior, in 1995, the DOJ substantially increased the penalties for antitrust violations. Prior to 1995, the largest criminal fine was $6 million. In contrast, the *average* criminal fine was in excess of $6 million after 1996. Total fines imposed in 1997 and 1998 were "virtually identical to the total fines imposed in all of the Division's prosecutions during the 20 years from 1976 through 1995." In 1999, total fines imposed exceeded $1.1 billion.[18]

The revised leniency program resulted in a surge in amnesty applications. Under the old policy, the Division obtained about one amnesty application per year, whereas the new policy generates more than one application per month.[19] The Deputy Assistant Attorney General of the Division remarked "The early identification of antitrust offences through compliance programs, together with the opportunity to pay zero dollars in fines under the Antitrust Division's Corporate Amnesty Program, has resulted in a 'race to the courthouse,'..." Indeed, it is not uncommon for a company to request amnesty a few days after one of its coconspirators has already secured amnesty by filing first.[20]

Some well-known examples of collusive behavior thwarted via the leniency policy include graphite electrodes production, vitamin sales, fine arts auctions, and USAID construction. Each of theses cases involved multimillion dollar fines to the coconspirators and in some cases criminal sentences, whereas the amnesty applicant incurred no criminal fines and received prosecution protection. In the graphite electrodes investigation, the second company to file paid a $32.5 million fine (10% of annual earnings), the third a $110 million fine (15% of

[17] While the empirical evidence to date suggests that the leniency policy is effective in curbing collusive behavior, it is theoretically possible that the policy could have the opposite effect. Cartels are illegal, and therefore, no written contract between member firms exists. As a result, colluding firms must rely on trust to enforce the collusive behavior. If firms deviate from the collusive agreement, other members have a powerful punishing tool in the leniency policy: deviation is punished by another member reporting the cartel (and gaining antitrust protection). Hence, the leniency policy may foster cartel behavior in that it provides a tool that can be used to discourage deviations from collusive agreements. See Spagnolo (2000).

[18] See Brown and Burns (2000), Kobayashi (2001), and Spratling (1999) for more details.

[19] The number of amnesty applications has not decreased over time. Indeed, from October 2002 to March 2003 amnesty applications reached a high of three per month.

[20] Antitrust Division, US DOJ, Annual Report FY 2001.

annual earnings), and the fourth a $135 million fine (28% of annual earnings). Mitsubishi was later convicted at trial and was sentenced to pay $134 million (76% of annual earnings). Executives from these companies incurred fines and criminal prison sentences. In the vitamin investigation, F. Hoffmann-La Roche and BASF AG plead guilty and incurred fines of $500 million and $225 million, respectively. Again, executives from these companies served time in prison. In the fine arts auctions case Sothebys paid a $45 million fine, and the chairman was sentenced to one year in jail and a $7.5 million fine. Finally, in the USAID Construction case, firms were ordered to pay fines of $140 million and to pay $10 million in restitution to the U.S. government. An executive for one of the companies received a three year prison sentence.[21]

Figure 1 shows the number of new RJV filings for all research areas (the solid line) and filings for Telecommunications specific RJV research areas (the dashed line). The vertical line denotes the revision of the leniency policy. The figure shows that firms in telecommunications reduced their RJV applications after the revision of the leniency policy. RJV filings across all research areas showed a sharp decline later in 1995, which may be due in part to the leniency policy revision and to the sharp increase in fines implemented in 1995. Obviously there may be many reasons for firms to reduce their RJV applications. However, this figure suggests that the decline in RJV applications may be due, at least in part, to the changes in policies regarding detection and punishment of collusive behavior via the leniency policy.

[21] Due to a 2002 revision in the British Office of Fair Trading (OFT) amnesty leniency policy there have been a number of high profile cartel breaking cases in the UK. These have involved bid rigging in construction business, supermarkets and dairies fixing milk prices, airlines setting fuel surcharges, and tobacco companies and supermarkets fixing the price of cigarettes.

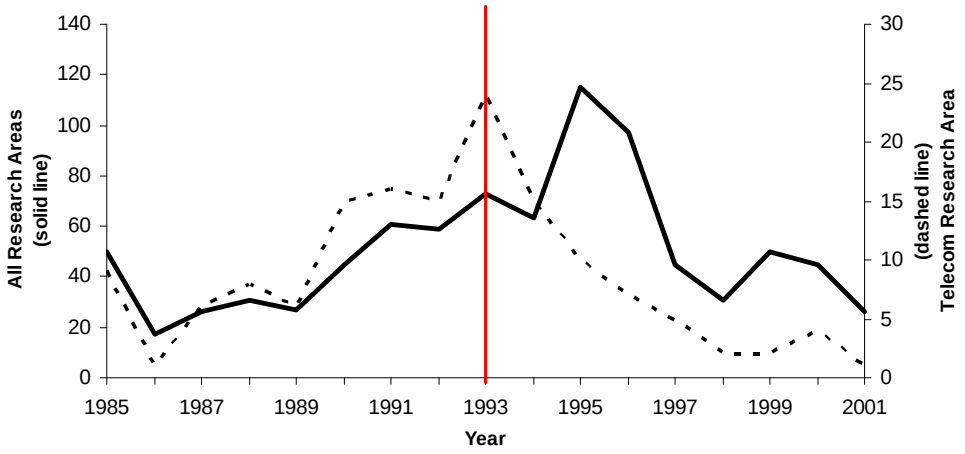

Figure 1: Number of New RJV Filings

3 Econometric Specification

In this section, we provide an econometric framework for understanding a firms decision to join an RJV. In subsequent sections we will use this framework to understand the implications of our quasi-experiment on firm RJV joining behavior.[22] The model describes the behavior of a firm conditional on the characteristics of the firm, the characteristics of the RJV, and the characteristics of the industry.

[22] We recognize that the decision of a firm to enter into an RJV will likely depend, at least in part, upon the decisions of rival firms (Bloch 1995; Greenlee and Cassiman, 1999; and Yi and Shin, 2000). We do not estimate a structural behavioral model of firms' decisions because of the difficulty of doing so in this framework. In particular, we would need to specify the game played among competing firms in R&D choices, RJV formation decisions, and final product market decisions. This game is best specified in a dynamic setting. To estimate the parameters of the model, the econometrician would need to address the simultaneity of R&D decisions, RJV formation decisions, and product market decisions. Furthermore, estimation would require assumptions regarding the nature of the equilibrium and a means to chose among multiple equilibria when necessary. Second, the main issue we wish to address concerns the nature of product market competition. Addressing this in a structural framework would require us to estimate two models of firm behavior in the final market (competitive and collusive). To determine which model better fits the data we could compare actual product markups to predicted markups under both models of product market behavior (à la Nevo, 2001). However, additional cost data would be needed to compute actual product markups, which are not easy to obtain and are often proprietary. Finally, the telecom industry is under regulation for a large part of the time period. Hence, our structural model would have to address strategic behavior in a regulated industry. For these reasons we do not present a structural model and instead estimate a descriptive model of the decision to form an RJV. The model presented below captures the potentially collusive intent of firms absent the additional structure and data requirements necessary to estimate a structural model.

3.1 The model

We develop a model of a firm's decision to enter into an RJV.[23] The unit of observation is a firm, RJV, time combination. Let V^*_{ijt} be the (latent) value to firm $i = 1, ..., N$ of engaging in RJV j at time t:

$$V^*_{ijt} = \alpha_1 L_{ij} + \alpha_2 L_{ij} H_{ijt} + \gamma_1 rd_{ijt} + \beta_1 x_{it} + \delta z_{ijt} + \varepsilon_{ijt}. \quad (1)$$

If firms enter into an RJV to facilitate collusion, antitrust policy targeted at product market collusion could impact the decision to engage in an RJV. The L_{ij} term is an indicator variable taking on the value of 1 if firm i joins RJV j after the leniency policy revision. Furthermore, the potential payoff to collusion in the product market could depend upon the market power of the RJV (the H_{ijt} term). This is best thought of as the collusive value to the firm of joining RJV j. We are primarily interested in the total effect of the leniency policy on RJV formation (determined by the $\alpha_1$and α_2 terms).[24] The remainder of the terms in (1) capture other potential motivations for RJV formation. The rd_{ijt} term represents the expected change in R&D intensity of firm i after entering RJV j, x_{it} are a vector of firm i characteristics, z_{ijt} are a vector of firm-RJV characteristics, and ϵ_{ijt} is an i.i.d. normally distributed mean zero stochastic term. We now discuss the terms of V^*_{ijt} in more detail.

Our measure of the market power of an RJV, H_{ijt}, is motivated by the observation that the larger the joint market shares of the firms engaged in collusive behavior (via the RJV) relative to the other firms in the industry, the higher is the profit to split among members. Hence, the market power of the RJV should be a function both of the market shares of the members as well as the overall level of industry concentration. Furthermore, because we wish to measure the potential for product market collusion, the market power of the RJV should be relevant only among product market competitors, even though RJV members may be in different industries. Our simple measure of the market power of an RJV incorporates

[23] Aspects of our econometric specification parallel Roller, et al (2007), who examine the impact of firm asymmetries on RJV formation. We are interested in determining whether firms enter into RJVs as means to facilitate product market collusion. While our study addresses a different issue, the model is still one involving RJV formation, and hence our estimation strategy is similar to theirs.

[24] We estimate two variations of the model, one with a level effect of the $H_{ijt}L_{ij}$ and another with a spline in the H_{ijt}.

these observations. Specifically, suppose firm i belongs to the industry classification k, and let N_{kj} be the subset of firms in industry k that are engaged in RJV j. Then we define the industry market power of the RJV as

$$H_{ijt} = \frac{\sum_{r \in N_{kjt}} s_{rt}^2}{HHI_{kt}} \tag{2}$$

where s_r is the market share of firm r computed as sales of firm r over total sales in industry k and HHI_{kt} is the Herfindahl Index for industry k.[25] Why this is a relevant measure of the RJV market power is best understood from the perspective of firm i who is considering joining RJV j. When making this decision firm i may be interested in asking how much collusive potential will joining RJV j yield? The number and size of firms in his market is fixed (the denominator) so in assessing the collusive potential of the RJV he will consider his size as well as the size of the other firms in the RJV relative to the overall industry concentration. Notice if all firms in his industry k joined RJV j then $H_{ijt} = 1$ indicating the RJV has very high market power. If there were only a few large firms in industry k then the RJV would require fewer members to have substantial market power. Naturally, an RJV in which most of the firms in the industry are members has more collusive potential, which is captured by our measure of RJV market power. That is, holding the HHI of the industry fixed, the greater the number of participants and the greater their market shares the greater will be H_{ijt}. Notice that we cannot use our measure of RJV market power to compare across industries.[26]

As many papers in the RJV literature show, the expected impact on R&D may be an important motivation for joining an RJV. For instance, firms may engage in RJVs to take advantage of complementarities among member firms, share R&D related costs, or overcome free-rider problems. As in Roller, et al (2007), we define rd_{ijt} as the change in R&D intensity of firm i that would result from joining RJV j at time t. It is given by

$$rd_{ijt} = \frac{R\&D_{it-1}}{sales_{it-1}} - \frac{R\&D_{ijt}}{sales_{ijt}} \tag{3}$$

[25] We use three definitions of industry classification: 3-digit NAICS, 6-digit NAICS, and a more narrow market definition for telecom firms using data from the FCC. We discuss this in more detail in section 5.

[26] That is, holding fixed the partipants and their market shares, the greater the HHI of the indusry the lower is H_{ijt}.

where $R\&D_i$ represents firm i expenditures on R&D and $sales_i$ represents gross dollar sales of firm i.

Following the findings of the RJV formation literature, we include control variables that may impact RJV formation decisions.[27] Firm-specific terms are captured by x_{it} and include firm size ($assets_{it}$), measures of the market power of firm i (market share and industry concentration) and the number of other RJV's in which i is currently engaged. RJV-specific terms are included in the z_{ijt} term. These are the number of members of RJV j, whether the intent is to patent the RJV outcome, patent interacted with market share, and the RJV market power (H_{ijt}). We also include variables designed to capture the attractiveness of a firm to other partners in the RJV. In addition to firm size, additional variables consist of a measure of firm size relative to the average RJV member ($rasset_{ijt}$) and a measure of capital constraints relative to the average RJV member ($rcapcon_{ijt}$). We include assets as a control for the capital and equipment that a particular firm brings to an RJV. We include free cash flow because much of R&D is funded from retained earnings. Firms with a high free cash follow should be more attractive partners in an RJV since they are able to sustain investment without loans or new equity issues. Finally, we include the firms annual assets as a measure of size and potential economies of scale the firm many have in R&D.

We define the measure of firm size relative to the RJV as

$$rasset_{ijt} = \frac{assets_{it-1} - avgassets_{jt-1}}{avgassets_{jt-1}} \tag{4}$$

where $avgassets_{jt-1}$ are average assets of all members of the RJV in the period previous to RJV j formation. Relative capital constraints, $rcapcon_{ijt}$, are similarly defined, where we use free cash flow from Compustat as a proxy for capital constraints.

Table 1 shows that firms that join RJVs join on average more than one. Hence, firm i will form RJV j at time t if the value to doing so is larger than the value to not doing so. Let V^*_{i0t} represent the value to firm i of not joining an RJV:

$$V^*_{i0t} = \gamma_0 rd_{it} + \beta_0 x_{i0t} + \varepsilon_{i0t}, \tag{5}$$

[27] For a summary of the literature see Caloghirou and Vonortas (2000) and Hagedoorn, et al (2000).

where rd_{it} is the average annual intensity of R&D undertaken by firm i when it is not in an RJV, and x_{i0t} are firm and industry specific effects. Hence, firm i will join RJV j if $V^*_{ijt} \geqslant V^*_{i0t}$ where V^*_{ijt} is given in equation (1). Notice that the number of feasible alternatives does not impact the decision to join a particular RJV, although our model allows the number of RJVs a firm is currently engaged in to impact the value to joining an RJV.

3.2 Estimation

We don't observe V^*_{ijt} or V^*_{i0t}, instead we observe whether firm i enters an RJV. Define

$$V_{ijt} \equiv \alpha_1 L_j + \alpha_2 L_j H_{ijt} + \gamma(rd_{ijt} - rd_{it}) + \beta(x_{it} - x_{i0t}) + \delta z_{ijt}. \tag{6}$$

As Roller, et al (2007) note, there are two issues regarding estimation, both relate to the observation that the value to firm i of joining RJV j is a function of $(rd_{ijt} - rd_{it})$. That is, firms consider the expected effect on R&D expenditures when considering whether to form an RJV. However, R&D intensity is influenced by RJV formation. Thus, the first issue to address in estimation concerns the endogeneity of R&D. The second issue concerns the effect on R&D from joining an RJV. We can construct $(rd_{ijt} - rd_{it})$ from the data when firm j joins an RJV. However, we do not observe rd_{ijt} if the firm is not engaged in an RJV. We need a consistent estimate of the expected effect of RJV formation on R&D intensity when an RJV is not formed. Following Roller, et al (2007), we estimate the parameters of the model using an endogenous switching model (Lee, 1978). The estimation procedure allows us to address the endogeneity and missing values issues and results in consistent estimates of all parameters.[28]

Estimation is based on the following equation of RJV formation

$$P_{ijt} = V_{ijt} + \eta_{ijt} \tag{7}$$

where $\eta_{ijt} \equiv \varepsilon_{i0t} - \varepsilon_{ijt} \sim N(0, \sigma^2_\eta)$.[29] We observe rd_{ijt} when firm i is engaged in RJV j:

$$rd_{ijt} = \lambda_1 w_{ijt} + u_{1it} \text{ if } V_{ijt} \geqslant \eta_{ijt} \tag{8}$$

[28] In general, industry HHIs are quite stable and changes in H_{ijt} (the RJV HHI) are caused by firms joining an RJV. This mitigates concern about the endogeneity of the HHI at the industry level.

[29] The parameters of V_{ijt} are identified up to the factor σ_n, hence we normalize $\sigma_n = 1$.

where w_{ijt} includes a constant, the market share of firm i, the number of members of RJV j, the number of RJVs firm i is currently involved in, the average size of the other firms in the RJV ($avgassets_{jt}$), capital constraints relative to the average RJV member ($rcapcon_{ijt}$), and industry fixed effects. Note that the coefficient on the constant term will pick up other effects on R&D of being in RJV such as cost-sharing.

If firm i is not engaged in RJV j we observe:

$$rd_{it} = \lambda_0 v_{it} + u_{0it} \text{ if } V_{ijt} < \eta_{ijt} \tag{9}$$

where v_{it} includes the number of RJVs firm i is currently involved in, market share of firm i, capital constraints faced by firm i, and industry fixed effects. We assume the errors $(u_1, u_0, \eta) \sim N(0, \Omega)$.

We estimate the model in stages. First, we get consistent estimates of the predicted probabilities ($\widehat{P}_{ijt}$) from a reduced form probit regression obtained by substituting equations (8) and (9) into (7). To control for the endogeneity of R&D, we correct (8) and (9) by including control variables constructed using the inverse Mill's ratio and the predicted probit probabilities $\widehat{P}_{ijt}$. We can then get consistent estimates of the corrected R&D equations by least squares estimation. We use the predicted values from the corrected R&D equations to construct the predicted difference in R&D intensity, $(\widehat{rd}_{ijt} - \widehat{rd}_{it})$, from joining an RJV for all firm-RJV combinations. We estimate the probit selection equation in (7) including the predicted R&D difference as a regressor, which Lee (1978) shows yields consistent estimates of the parameters. The parameters of our model are identified by i) the leniency policy exclusion restriction that should not impact R&D investments directly (equations (8) and (9)) rather only the decision to enter an RJV and ii) through nonlinearities arising from the inverse Mill's ratio which enters only through the corrected R&D equations.

Again our strategy to identify collusive intentions relies on the variation in RJV formation arising from the revision to the leniency policy. For this to be a reasonable quasi-experiment, the leniency policy should impact collusive behavior but not affect the other motivations to form an RJV. As discussed in section 2.2, there is sufficient evidence that the revision to the leniency policy has been successful in curbing collusive behavior. Furthermore, there is no evidence that the DOJ changed the leniency policy with an intention to influence RJV

formation or R&D investments directly.[30] Finally, in our model the effect of the leniency policy revision on RJV formation is allowed to vary with a continuous measure of RJV market power (H_{ijt}). Hence, we do not have to rely on a discrete law change to identify potentially collusive efforts. While it is possible that some unknown policy impacted the propensity to join an RJV at the same time the leniency policy was revised, it seems unlikely that this hypothetical policy would vary with the RJV market power measure as well.

There are a few corrections we must make to obtain correct standard errors. First, only a small fraction of firms join an RJV in a given year (on average 2%). As we will discuss in the next section, we employ choice based sampling for our "across industry" sample, and hence, our standard errors need to be corrected for this reweighting. Second, as Bertrand, Mullainathan, and Duflo (2004) show for difference-in-difference studies focusing on variation across states and years, errors may be correlated even after controlling for fixed effects. In our setting, errors may be correlated across firms and, hence, should be adjusted to account for serial correlation. We address both these issues by clustering standard errors and bootstrapping at the firm level, which preserves the within cluster feature of the errors (see Cameron, Gelbach, and Miller, 2007).[31]

4 Data

Our data cover the period 1986-2001.[32] As discussed in section 1, we construct two samples: an across industry sample and a telecom markets sample. Information on RJVs comes from the CORE database constructed by Albert Link (Link, 1996) and includes the name of the RJV, date of filing, general industry classification, and the nature of research to be undertaken. We augment the CORE data with the names of the member firms in each

[30] The revision appears to have been motivated by the desire to thwart international cartels. See www.usdoj.gov/atr/public/speeches/206611.htm.

[31] We also present results from a fixed effects models when we discuss our robustness checks.

[32] Link and Bauer (1989) document that cooperative research efforts were occuring informally before the NCRA was implemented in 1984. It is likely that RJV applications in 1985 may capture a portion of the pre-1985 stock. For this reason we include all RJVs starting in 1986.

RJV in our time frame, as reported in the Federal Register.[33]

If firms add members to the RJV they are required to refile with the FTC, therefore we observe changes in the composition of RJV membership across years. Unfortunately, firms do not refile when the RJV is terminated. As a result, we observe new RJVs and changes to RJV membership, but not end dates. In practice many RJVs do not span the period of our data; an RJV formed in 1986 is not likely to be around for new firms to join in 2001. We had to make some assumptions regarding the set of potential RJVs available for each firm to join (i.e. the choice set). We decided to "end" an RJV in the year that we last observe a member join.[34] Imposing this restriction, our sample consists of 386 RJVs with an average length of three years.[35]

Firm-level data come from the U.S. Compustat database, which includes industry classification, assets, sales, free cash, and R&D expenditures for over 20,000 publicly traded firms. There are a few data issues to address. First, small firms are underrepresented. They are less likely to file an RJV application with the FTC since they are less likely to be subject of antitrust investigation, and they are less likely to be in the Compustat database.[36] As a result of losing small firms, we observe a few RJVs with only one member, which we drop. In addition, there are some RJVs for which there are no members in the same 3-digit NAICS industry. We also drop these RJVs from our sample because firms that are in different industries are unlikely to be competitors in final goods production.[37]

We restrict our attention to industries that contain at least one firm that joins an RJV between 1986 and 2001. Even after this restriction, we still have 27 (3-digit NAICS) industries that contain at least one RJV joiner. In our data, an industry may have as many as

[33] See http://www.gpoaccess.gov/fr/index.html.

[34] Our results are robust to changes in our end date assumption. See section 5.

[35] For more description of the RJVs filed under NCRA see Link (1996), who provides an overview; Majewski and Williamson (2002), who examine contract details of 96 NCRA applicants; and Berg, et al (1982).

[36] The Compustat data do not contain information on non-publically traded firms or non-profit firms.

[37] Hence, our data are a nonrandom selection of firms. The selection is the same across RJV joiners and non-joiners, hence we should not have any single-sided effects that could impact the estimates of our control variables. The selection process will cause us to miss potentially collusive behavior among smaller firms making any support we find for collusive behavior more conservative than when small firms are included.

thirty-one ventures operating in any given year. We are interested in estimating the probability a firm joins any number of possible RJVs in a given year. Constructing a sample consisting of all possible firm-year-RJV combinations would yield a dataset of unmanageable size. Furthermore, joining an RJV is a rare event. However, we are interested in the impact of the amnesty program on the probability of joining a venture, so we wish to learn from decisions made by a small proportion of the firms. To address both of these issues, we construct a smaller sample of a subset of firms where we oversample firms that join an RJV. To correct for the bias due to oversampling we use Manski and McFadden's (1981) method of choice based sampling. Specifically, we divide our sample into firms that are not involved in a venture between 1986 and 2001 and firms that joined at least one RJV during the period. We then use all firms with complete Compustat data that joined a venture and the same number of non-joiners from each subset making the sample proportion approximately 50% for each group. Since we have the population of all RJV joiners we know the true proportion in the sample is 7% for firms that ever join an RJV during the sample period (i.e. 93% for non-joiners) thus we can construct a weight that scales down joiners and scales up non-joiners.[38] Our across industry sample consists of 1,651 firms yielding 13,399 firm years and 133,654 firm-year-RJV observations.[39]

The firm's choice set requires some additional explanation. One option would be to assume that every firm in the sample could join every RJV we ever observe in the data. Given that there are thousands of RJVs in the sample and tens of thousand of firm years this is computationally infeasible. It also assumes that all firms could contribute to any RJV. To narrow the viable options we assume a firm could join any RJV that exists in a

[38] Because logits and probits perform poorly when one type of event is thousands of times less likely than another, in our case joining a RJV (a one) is far less frequent each year than not joining (a zero) we reweight the sample to make joining more frequent than it is in the underlying population. This requires weighting the sample so the parameter estimates reflect the population sample impacts not the reweighted sample. Specifically our weight is (.07/53)∗joiners +(.93/.47)∗non-joiners. We correct the standard errors to account for this sample weighting scheme. See Manski and McFadden (1981).

[39] Note that our selection criteria is whether a firm joined an RJV. One may be concerned about sample selection bias. However, selection bias is mitigated given the panel aspect of our data. Since the data are a firm-RJV-year panel, a firm will potentially have a number of years in which it does not join an RJV and a number of years during which it could potentially join (i.e. other members of its industry have joined) but it does not. In many ways the estimation strategy is to estimate a panel of the probability of joining but to include those firms that never join to allow for systematic differences between the two groups.

given year in which the firm exists. We further refine the choice set to include only those RJVs in which at least one firm in the same industry joins.

To make the explanation complete, consider an example involving AT&T starting in 1986. AT&T's choice set in 1986 includes all RJVs in 1986 in which at least one telecommunication firm has joined. For the telecommunications sample, AT&T's choice set in 1986 consisted of three RJVs of which it joined one. In 1987 two new RJVs that included telecommunications firms formed, so AT&T's choice set in 1987 is four (the two continuing from 1986 which it did not join and the two new RJVs). It joined two of these. No telecommunications firms joined an RJV in 1988, so AT&T choice set in 1988 consisted of two RJVs (the two continuing from 1987 which it did not join) of which it joined one. Hence, the number of RJVs in AT&T's choice set (and the total number RJV joined) in each consecutive year is 3(1), 4(3), and 2(4). AT&T's choice set continues to evolve over the sample period with new RJV being created and entering the choice set while others exit either because the firm joins or our ending rule removes the RJV from all the choice sets.

Table 1 presents descriptive statistics for the Compustat database and our across industry sample. Due to our sampling scheme, our sample includes more firms that were engaged in RJVs and only includes industries in which at least one firm joined an RJV. Therefore, it is not surprising that firms in our sample undertake much more R&D and have more assets, free cash, and sales than an average Compustat firm. We present two measures of industry concentration, the 6-digit and 3-digit Herfindahl index (HHI) calculated as the sum of squares of the market shares of all firms in either the 6-digit NAICS or 3-digit NAICS industry, respectively. Measures of industry concentration at both aggregation levels are similar in the Compustat data and in our sample. The data also indicate that firms that join RJVs join on average three RJVs. Finally, on average only 2% of firms join an RJV in any given year.

	Firms in Compustat		Our Sample	
	Mean	Std Dev	Mean	Std Dev
Market Share (6 digit NAICS)	0.109	0.240	0.102	0.211
Market Share (3 digit NAICS)	0.011	0.050	0.010	0.034
Sales	1.468	7.264	5.042	15.960
Cash	0.122	0.908	0.462	1.937
HHI for 6 digit NAICS	0.280	0.253	0.237	0.210
HHI for 3 digit NAICS	0.082	0.088	0.058	0.062
Assets	3.307	23.618	10.555	49.191
R&D expenditures	0.058	0.381	0.263	0.830
Proportion of firms join an RJV			0.021	0.142
# RJV joined all firms			1.721	4.748
# RJV joined among joiners			3.292	6.162

Notes: Observation is a firm-year pair. Sales, cash, assets, and R&D expenditures are in billions of chain weighted 2004$.

Table 1: Descriptive Statistics for Across All Industries

When considering the collusive intent of firms it is important to be certain that the level of aggregation is not too broad, so as to include more firms than the relevant antitrust market, nor to narrow, so as to exclude potential rivals.[40] This is difficult to address in a sample spanning many industries. However we address it directly in the telecom markets sample.[41]

Specifically, we consider five different definitions of the relevant telecom antitrust market. At the most aggregate (3-digit NAICS) industry level we consider two potential markets: firms in "Broadcast Telecom" (NAICS 513) and firms involved in a "Telecom RJV" (stated as the primary research area in their RJV filing). There are reasons to believe that this level of aggregation may be too broad. For instance, Broadcast Telecom includes wired telecommunications carriers, radio stations, television broadcasters, cable providers, and wireless carriers, which are not always competitors with each other. The Telecom RJV research area also includes firms that are often in different competitive markets. For instance, it includes firms in publishing (NAICS 511), chemical manufacturing (NAICS 325), and computer and electronic manufacturing (NAICS 334). Indeed the descriptive statistics

[40] See Werden (1988) and Pittman and Werden (1990) for a discussion of the divergence between industry classifications and antitrust markets.

[41] Both because the telecommunications industry does not have many firms and due to the high proportion of firms in this industry that join an RJV, we do not need to use choice-based sampling to construct our telecom sample.

in the first panel of Table 2 indicate these two markets look very different, with the Broadcast Telecom market being less concentrated but more research intensive.

Source of Firm Data:	Compustat				FCC	
Level of Aggregation:	3 Digit NAICS		6 Digit NAICS		Long Distance Firms	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
	Broadcast Telecom		Wired Telecom		All Years	
HHI	0.16	0.15	0.05	0.01	0.40	0.14
Market Share	0.08	0.13	0.02	0.03	0.03	0.11
R&D expenditures	0.55	1.21	0.77	1.38	0.91	1.63
Sales	8.45	17.06	13.34	20.72	2.57	9.25
Assets	18.34	36.23	27.05	39.67	22.43	34.72
Proportion join RJV	0.02	0.14	0.02	0.14	0.07	0.25
	Telecom Research Area				Regulated Years	
HHI	0.25	0.22			0.46	0.11
Market Share	0.14	0.23			0.03	0.12
R&D expenditures	0.37	0.73			1.20	1.85
Sales	5.03	9.30			2.45	9.43
Assets	5.63	10.24			22.24	24.20
Proportion join RJV	0.02	0.14			0.07	0.26

Notes: Observation is a firm-year pair. Sales, cash, assets, and R&D expenditures are in billions of chain-weighted 2004$. Based on firms in our telecommunications sample.

Table 2: Descriptive Statistics Telecom Markets

As we refine the relevant market to "Wired Telecom" (6-digit NAICS), the second panel of Table 2, we find a less concentrated market, where firms have even smaller market shares on average and engage in more R&D relative to their 3-digit counterparts. While significantly narrower, this may still be too broad to be the relevant antitrust market. Wired Telecom consists of all firms offering local and long distance telephony, which were not overlapping markets prior to 1996, during the period of telecommunications regulation.

Our final definition of the relevant market in telecom uses data from the FCC's Report of Common Carriers,[42] which permits us to further divide telecom firms into those offering long distance. Furthermore, the FCC data include all firms in telephony regardless of size. Our final two definitions of the relevant market consist of all firms offering long distance services. Over all years of the data (1986-2001) the market of long distance firms may still be too narrow since after 1996 long distance carriers were permitted to offer local services.

[42] See www.fcc.gov/Bureaus/Common_Carrier/ Reports/.

Therefore, we also consider a subset of the long distance market restricted to the years of regulation. Although the latter is a relatively small sample, this market definition is particularly attractive since, by law, the market includes only these firms and these firms are not permitted to enter other telecom markets. The third panel of Table 2 indicates that the market for long distance services is much more concentrated relative to our other antitrust market definitions. Furthermore, the long distance market was more concentrated during the period of regulation with an HHI suggesting it operated similar to an industry with two equally sized firms. Finally, on average more firms join an RJV (7%) relative to other telecom antitrust market definitions.

5 Results

In this section we present the results from our regressions using all industries in the Compustat data meeting our criteria of having at least one firm that joins an RJV during the sample period. We also present results focused on telecommunications for different definitions of the relevant antitrust market. As discussed in section 3, we include the following controls in all regressions: firm assets, market share, number of RJVs that the firm is a member of and its square, industry fixed effects, industry HHI, number of members of the RJV, differences in relative assets ($rasset$), differences in relative capital constraints ($rcapcon$), indicator of whether the intent is to patent the outcome also interacted with market share, time trend and its square. Our parameter estimates for the control variables are intuitive and consistent with the majority of the RJV formation literature findings. For instance, across all specifications, we find that firms with larger market shares and more assets are significantly more likely to engage in RJVs. The more RJVs a firm is engaged in the more likely they are to join another RJV but there are decreasing returns to joining. Firms in less concentrated industries and industries where patents are not as important are significantly more likely to form RJVs. Finally, more relatively capital constrained firms are more likely to join an RJV. Given that the focus of this paper is on the collusive intent underlying RJV formation, we do not report the parameter estimates for the controls across the specifications

and samples.[43] We now discuss the results of the variables of interest in detail.

If the primary motivation for a firm to join an RJV is to foster collusion in the product market, the impact of RJV formation on R&D is a second-order consideration, at best. For this reason, we estimate two different model specifications for all market definitions and samples. The first, the "Without R&D Effects" specification, consists of a model of RJV formation without predicted change in R&D intensity as a regressor. Note that this specification is equivalent to the first stage in the two-stage procedure discussed in section 3.2. Estimates of the control variables from the Without-R&D-Effects specification will not be consistent if firms consider the predicted change in R&D when making RJV formation decisions. Our second specification, "With R&D Effects", addresses this by correcting for the endogeneity of R&D and RJV decisions as outlined in section 3.2.

Given the orthogonality of our policy experiment to the impact on research associated with joining an RJV we are not concerned that the endogeneity of R&D spending could contaminate the Without-R&D-Effects estimates. However, one potential difficulty is that our experiment may affect R&D through the "back door." For example, because the collusive benefits of the RJV are reduced, the R&D benefits that would have occurred (in the absence of the leniency policy) are not realized in the revised leniency policy environment. Controlling for R&D endogeneity allows us examine the impact of the policy holding R&D intensity constant. Thus, we have estimates of collusive behavior that are not contaminated by the potential "back door" effects of the leniency policy on R&D. We present the results from both R&D-Effects specifications for the across industry and telecom market samples.[44] We report the pairs clustered bootstrap p-values (in square brackets) and the non-bootstrap cluster-robust standard errors (in parenthesis).[45] Our primary motivation for bootstrapping

[43] These are available from the authors upon request.

[44] We do not present the parameter estimates for the corrected R&D equations across all specifications and samples because of space considerations and since this paper is not focused on the determinants of R&D. Again, our estimates are intuitive. For most specifications we find that firms with higher market share are significantly more likely to have higher R&D intensity; the more RJVs a firm is a member of the lower is its R&D intensity in any one RJV; and the more capital constrained is a firm the lower is its R&D intensity. Finally, in most specifications, correcting for endogenous R&D is necessary (i.e. the parameter estimates on the inverse mills correction terms are significant).

[45] The pairs clustered bootstrap with clustered dependence involves resampling entire clusters, in our

is to correct the standard errors for the endogeneity of R&D, which is a potential problem in the With-R&D-Effects specification. Computing bootstrapped p-values is computationally intensive,[46] hence we compute the bootstrapped p-values for the With-R&D-Effects specification only. We note that, in the majority of cases, the bootstrapped p-values result in the same significance level as the non-bootstrapped clustered standard errors.

5.1 Results from Across Industry Sample

Table 3 presents the results for the across industry sample. To reiterate our test is whether the leniency policy and leniency policy interacted with the RJV measure of market power are statistically significant. We cannot predict whether the individual effects will be positive or negative and in fact the effects could differ for different subgroups. For policy purposes, however, the overall effect is of particular interest since they tell us the average impact of the leniency policy on RJV formation. The first columns of the Without- and With-R&D-Effects specifications include the post leniency policy revision as a regressor. The results suggest that, holding industry, firm, and RJV characteristics constant, the revision of the leniency policy resulted in a significant reduction of the probability a firm joins an RJV in the set of available RJVs open to the firm. The parameter estimates for both specifications are significantly negative at the 1% level, where the impact of the leniency revision is stronger when predicted change in R&D intensity is included.[47]

case firms, rather than individual observations (i.e. a firm-possible RJV-year combination). As such the resampling preserves the correlation structure among the observations in the original data.

[46] For each parameter, we computed a bootstrap p-value by constructing the empirical distribution of bootstrapped t-statistics by taking 10,000 draws of t-statistics.

[47] The With-R&D-Effects specification includes the effect of the predicted difference in R&D. The parameter estimates are significant and negative suggesting cost sharing is a motivation for firms to form an RJV.

Selected Variables	Specification					
	Without R&D Effects			With R&D Effects		
Post Leniency Policy Dummy	-0.287***	-0.314***	-0.266***	-0.395***	-0.436***	-0.350***
	(0.05)	(0.05)	(0.06)	(0.05)	(0.06)	(0.06)
				[0.000]	[0.000]	[0.000]
Interactions with Post Leniency Policy						
RJV HHI		0.13			0.202**	
		(0.09)			(0.09)	
					[0.001]	
RJV HHI * 1(RJV HHI lowest quartile)			-8.91			-14.017**
			(6.42)			(6.70)
						[0.001]
RJV HHI * 1(RJV HHI second quartile)			-0.19			-0.84
			(0.70)			(0.75)
						[0.102]
RJV HHI * 1(RJV HHI third quartile)			-0.485**			-0.748***
			(0.21)			(0.23)
						[0.000]
RJV HHI * 1(RJV HHI highest quartile)			0.10			0.12
			(0.09)			(0.09)
						[0.044]
RJV HHI	0.353***	0.267***	0.260***	0.372***	0.243***	0.234***
	(0.07)	(0.09)	(0.09)	(0.07)	(0.09)	(0.09)
Predicted R&D difference				-0.651***	-0.651***	-0.703***
				(0.07)	(0.07)	(0.08)
				[0.000]	[0.000]	[0.000]
Total Effect of Leniency Policy	-0.0027***	-0.0027***	-0.0026***	-0.0034***	-0.0034***	-0.0032***
Chi Square Test Statistic	NA	38.42	53.40	NA	68.85	89.44
Prob > Chi Square		0.00	0.00		0.00	0.00
Observations: 133654						
Number of Industries: 27						
Number of RJVs: 368						
Number of Firms: 1651						

Notes: Standard errors clustered by firm are in parenthesis. P-values generated by pairs cluster bootstrap are in brackets. * indicates significant at 10%; ** at 5%; *** at 1%. An observation is a firm, RJV, year combination. All specifications include the following controls: firm assets, market share, number of RJVs of firm and its square, industry fixed effects, industry HHI, number of members of RJV, asset difference (rasset), capital constraint difference (rcapcon), dummy for patent patent * market share, time trend and its square. Total effect of the leniency policy is computed at the mean value of the independent variables.

Table 3: Probit of Join an RJV Across All Industries

To gain insight into the role RJV market power plays in the decision to form an RJV we interact the post leniency policy variable with H (the RJV HHI measure) and a spline in H. We find that the effect of the revision of the leniency policy on the probability of joining an RJV varies with our measure of RJV market power. The results with the interaction of leniency and H are presented in the second columns of the R&D specifications. In both specifications, the parameter estimate on the interaction term is positive (although smaller in magnitude than the estimate of level effect of the leniency policy) and is significant (at the 5% level) in the With-R&D-Effects specification. Its positive coefficient indicates that, while

firms are less likely to join an RJV after the revised leniency policy, the effect is mitigated as the HHI of the RJV increases. To examine this in more detail, we decompose H by quartiles. The results of the leniency policy interacted with the H spline are presented in the final columns of both R&D specifications. The third quartile interaction is the only interaction that has a significant impact in both R&D specifications, with the lowest quartile interaction also significant in the With-R&D-Effects specification. Although the splines are imprecisely estimated, the pattern is broadly consistent with our hypothesis that the DOJ's revised leniency policy changes the threshold at which a firm is willing to join an RJV by reducing the collusive potential of the venture. One potential problem in interpreting these results is that H differs across industries and is of a similar magnitude within industries. Hence, while industry fixed effects are included as control variables, it may still be that the H spline results are reflecting differences across industries in RJV market power. We are able to better address this issue in our telecom sample, which includes fewer industries and, in some market definitions, only one industry.

In the final rows of Table 3, we present the total effect of the revised leniency policy on the probability of joining an RJV. The total effect is computed as the difference in the predicted probit probability ($\widehat{P}_{ijt}$) under a revised leniency policy versus the probability of joining under no leniency policy, evaluated at the mean of the regressors. Notice that the total effect is negative and significant (at the 1% level) and of approximately the same order of magnitude within R&D-Effects specifications.[48] The total effect for a firm with an HHI equal to the mean is -0.27% without controlling for the predicted R&D difference and -0.34% in the With-R&D-Effects specification. To put this impact into perspective, the probability a firm joins an RJV in its choice set is 2%. Thus a 0.27 drop in the probability is approximately a 13% decrease in the probability a firm joins one of the RJVs in its choice set.[49]

[48] The parameter estimates of the leniency policy control and leniency interacted with the RJV HHI are jointly significant (as indicated by the results of a chi-square test).

[49] Given the method used to construct our sample we may in fact be underestimating this probability. If no firm joins an RJV then we remove it from the choice set of all firms. Thus if RJVs are systematically exiting the sample due to the leniency policy we would underestimate the impact of the revised leniency policy on RJV formation.

	Level of Aggregation				
	3 Digit NAICS		6 Digit NAICS	Long Distance Carriers	
	Telcom Research Area	Broadcast Telecom	Wired Telcom	All Years	Regulated Years
Without R&D Effects:					
Post Leniency Policy Dummy	-0.260***	-0.892***	-0.849***	0.007	0.148
	(0.087)	(0.211)	(0.283)	(0.229)	(0.188)
RJV HHI*Post Leniency Policy	-0.437***	0.714*	0.685	-0.737*	-1.184***
	(0.168)	(0.421)	(0.456)	(0.423)	(0.354)
RJV HHI	0.726***	-0.175	0.091	0.42	0.447
	(0.166)	(0.255)	(0.456)	(0.498)	(0.535)
Total Effect of Leniency Policy	-0.004***	-0.009***	-0.015***	-0.052	-0.056***
Chi Square Test Statistic	41.24	21.52	12.06	4.57	11.54
Prob > Chi2	0.00	0.00	0.00	0.10	0.00
With R&D Effects:					
Post Leniency Policy Dummy	-0.406***	-0.960***	-0.905***	0.005	0.122
	(0.094)	(0.234)	(0.309)	(0.229)	(0.226)
	[0.000]	[0.000]	[0.000]	[0.974]	[0.749]
RJV HHI*Post Leniency Policy	-0.458***	0.751**	0.694	-0.739*	-1.268***
	(0.174)	(0.356)	(0.462)	(0.440)	(0.332)
	[0.000]	[0.008]	[0.055]	[0.090]	[0.013]
RJV HHI	0.869***	-0.207	0.106	0.425	0.446
	(0.168)	(0.268)	(0.457)	(0.566)	(0.538)
Predicted R&D Difference	-0.585***	-0.108	-0.083	2.0156	-4.562
	(0.771)	(0.098)	(0.096)	(46.760)	(25.224)
	[0.000]	[0.093]	[0.209]	[0.961]	[0.820]
Total Effect of Leniency Policy	-0.005***	-0.010***	-0.016***	-0.052	-0.068***
Chi Square Test Statistic	65.99	18.11	11.00	3.81	14.60
Prob > Chi2	0.00	0.00	0.00	0.15	0.00
Number of Observations	36093	7051	3846	1073	610

Notes: Standard errors clustered by firm are in parenthesis. P-values generated by pairs-cluster bootstrap are in brackets. * indicates significant at 10%; ** at 5%; *** at 1%. All regressions include the additional controls: firm assets, market share, number of RJVs of firm and its square, industry fixed effects, industry HHI, number of members of RJV, asset difference (rasset), capital constraint difference (rcapcon), dummy for patent, patent * market share, time trend and its square. Total effect computed at mean of independent variables. An observation is a firm-year-RJV combination.

Table 4: Probit of Join RJV in Telecom Markets

5.2 Results from Telecommunications Sample

As noted above we are concerned that the NAIC code may not property measure the industry in which firms in the RJV compete. For this reason we turn to the telecommunications industry specifically. The telecommunications industry is a large component of our sample and 38% of the firms in the industry were involved the sample. Telecommunications firms also have a more defined final product market than many other firms in our sample. The Federal Communications Commission (FCC) also provides data on the sales of all firms

by line of business making the computation of the RJV's market power much easier than when we use the COMPUSTAT data. We are particularly confident about the market power measures for long distance carriers between 1984 and 1996 when the Federal Communications Commission only allowed firms to sell local or long distance service. During this period we can easily identify the relevant markets and competitors.

Table 4 presents the results for the telecom sample. As Figure 1 showed, telecommunications research areas exhibited a downward trend in RJV applications around the time the leniency policy was revised. As discussed earlier, we estimate the model under various levels of aggregation. As the table indicates, the results of the total effect of the leniency policy are significantly negative across all but one definition of the relevant antitrust market and across R&D-Effects specifications. These estimates suggest that the total effect of the leniency policy was to significantly reduce RJV applications among telecom firms. This effect becomes larger (in absolute value) as the market definition narrows and is most pronounced for the long distance carriers over the period of regulation.

In column 1 we present the results for all firms in industries joining an RJV focused on Telecom research. The total effect is about -0.005 implying that the leniency policy revision results in a 25% reduction in the 2% probability of joining a venture in the firm's choice set. The negative total effect is consistent with the results we found for all industries but in Telecom research the reduction in the probability of joining is even larger as the HHI of the venture increases. When we narrow the market definition to Broadcast Telecom the total effect of the leniency policy is larger (about -0.01) and results in nearly a 50% drop in the likelihood a firm joins an RJV. For Wired Telecom, a highly concentrated and narrowly defined market, the total effect of the leniency policy rises to an 80% reduction in the probability a firm joins a venture in its choice set. Finally, turning to the narrowest of our market definitions, Long Distance Carriers, we find almost a 100% change in the likelihood of joining an RJV following the leniency policy revision. This dramatic reduction is consistent with the trend observed in Figure 1 in which joint ventures dramatically decline following the policy's revision (the number of new RJVs falls to almost zero by 2001).

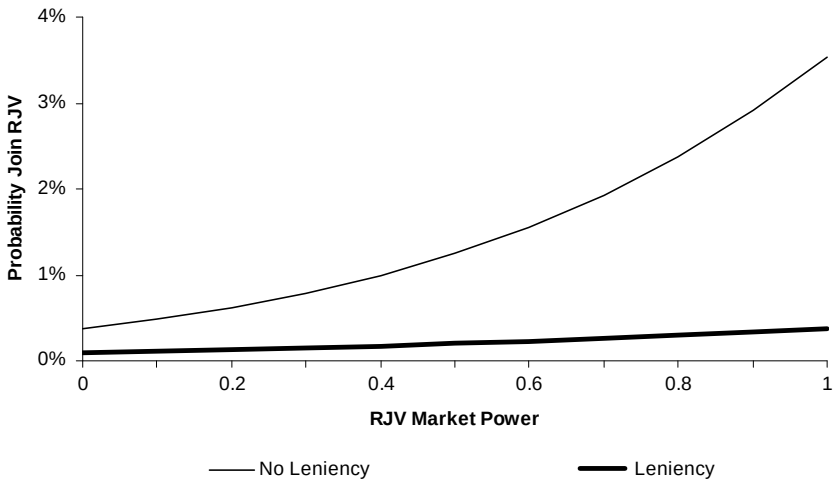

Figure 2: Leniency Policy Effects on Probability Join RJV in Telecom Research

While informative, the total effect is calculated at the mean of all variables. However, it is worthwhile to examine how the total effect of leniency policy varies across all values of the H.[50] Figures 2 and 3 illustrate the total effect of the leniency policy revision on the probability of joining an RJV across H. Figure 2 presents the total effect for the Telecom RJV research area and Figure 3 for Long Distance Carriers (both for the With-R&D-Effects specification). The figures reveal that the higher the market power of the RJV, the more an impact the leniency policy has on the decision to join an RJV. Both figures reiterate the previous results, namely the probability of joining an RJV is lower after the leniency policy is implemented. Furthermore, they show that as RJV market power increases the probability of joining an RJV increases when there is no leniency policy. When there is a revised leniency policy, the probability of joining a Telecom focused RJV is lower, but otherwise not impacted by the market power of the RJV. However, among Long Distance Carriers, the probability of joining declines in the market power of the RJV when there is a leniency policy. These results suggest that the higher the market power of the RJV the more collusive potential it has, which results in a differential effect of the leniency policy on the probability of joining an RJV.

[50] Recall, if all firms in industry k are in RJV j then the RJV Herfindahl would be the highest possible ($H_{ijt} = 1$) indicating the RJV has very high market power in that industry. If there were only a few large firms in industry k then the RJV would require fewer members to have substantial market power.

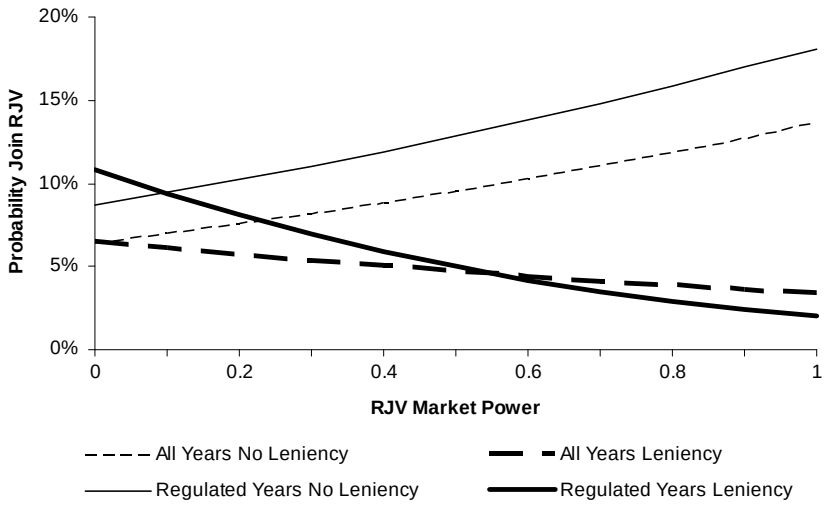

Figure 3: Leniency Policy Effects on Probability Join RJV in Long Distance Market

We find that, even after controlling for industry concentration, the market power of the RJV significantly impacts RJV formation decisions. Furthermore, the revised leniency policy has a dramatically different impact on high market power RJV formation. The results are consistent with RJVs that have a high market power becoming less attractive after the leniency policy, a fact that is difficult to reconcile with RJVs having no collusive properties.

5.3 Robustness Checks

We conducted a number of robustness checks involving different model specifications, definitions of variables, and changes in time frame. Our first robustness check considers that, in our descriptive framework including controls for observable industry, RJV, and firm characteristics may not be sufficient as there may be unobserved firm- or RJV-specific factors that affect the value of entering an RJV. To allow for this, we estimate a number of fixed effects logit models of the decision to enter an RJV.[51] The results from the fixed effects regressions across all industries and the telecom markets are presented in Table 5.[52] Note

[51] Due to the "incidental parameters problem," a fixed effects probit regression will not give consistent estimates of the parameters. The logit does not suffer from this problem. See Greene (2000) for a discussion.

[52] Due to the sample weighting scheme we can't estimate firm fixed effects in the across industry sample. Recall we chose the sample to be all joining firms and an equal size of non-joining firms, hence including firm fixed effects would completely predict not joining for half the sample.

that the total effect of the revised leniency policy does not change when firm and RJV fixed effects are included. The effect is significant and negative across almost all specifications. We include the results without any fixed effects to facilitate comparison across the logit and probit regressions. Again, the total effect is significant and negative across almost all specifications.

Level of Aggregation	Included Fixed Effects	Post Leniency Policy Dummy	RJV HHI* Post Leniency Policy	Chi Square Test Statistic	Number of Observations
All Industries	Industry	-0.825***	0.505*	27.25***	133654
(3 Digit NAICS)		(0.162)	(0.279)	[0.00]	
	RJV	-0.317	-1.357***	29.66***	132511
		(0.205)	(0.420)	[0.00]	
Telcom Research Area	Industry	-0.697***	-1.196***	41.13***	36093
(3 Digit NAICS)		(0.242)	(0.457)	[0.00]	
	Firm	-0.506*	-1.712***	57.57***	13169
		(0.265)	(0.581)	[0.00]	
	RJV	-0.451	-0.656	6.46**	36000
		(0.370)	(0.710)	[0.040]	
Broadcast Telcom	None	-2.542***	2.360*	20.48***	7051
(3 Digit NAICS)		(0.619)	(1.239)	[0.00]	
	Firm	-2.464***	2.740**	20.87***	4131
		(0.557)	(1.147)	[0.00]	
	RJV	-1.649	2.117	3.35	6396
		(1.052)	(2.320)	[0.187]	
Wired Telcom	None	-2.190***	2.121*	10.91***	3846
(6 Digit NAICS)		(0.727)	(1.167)	[0.004]	
	Firm	-2.319***	2.601**	13.69***	2762
		(0.653)	(1.120)	[0.001]	
	RJV	-2.354**	3.758	4.40	3314
		(1.191)	(2.531)	[0.111]	
Long Distance Carriers	None	0.111	-1.455*	3.52	1073
All Years		(0.447)	(0.866)	[0.165]	
	Firm	0.271	-1.695**	6.75**	552
		(0.545)	(0.840)	[0.034]	
	RJV	2.881	-8.596***	16.08***	1018
		(1.871)	(2.644)	[0.000]	
Long Distance Carriers	None	0.353	-2.195***	8.63**	610
Regulated Years		(0.388)	(0.747)	[0.013]	
	Firm	0.664	-2.195***	8.19**	334
		(0.448)	(0.747)	[0.017]	
	RJV	2.367	-10.828**	6.61**	555
		(2.272)	(4.551)	[0.036]	

Notes: Standard errors clustered by firm are in parenthesis. Chi Square p-values are in brackets. * indicates significant at 10%; ** at 5%; *** at 1%. All regressions include the additional controls: firm assets, market share, number of RJVs of firm and its square, industry fixed effects and HHI, # RJV members, asset difference, capital constraint difference, patent dummy, patent*market share, time trend and its square.

Table 5: Fixed Effects Logit Results of Join an RJV

We also conducted a number of robustness checks for different definitions of variables. The results of these additional robustness checks are not reported due to space considerations. First, a problem common to studies of R&D investments is that there are many firms for which a measure of R&D is missing. In the main regressions, we drop these missing R&D observations from our estimation of the R&D equations. To test if our results are sensitive to missing R&D measures, we replaced R&D with a zero when it was missing and reran the regressions. This substitution was motivated by the presumption that, if R&D is not important to a firm it is likely not to be reported (i.e. a missing value) which may be equal to zero in many cases. The results for the across industries sample change very little, and never in significance or sign. Our telecommunications samples are smaller and, hence, including more observations impacts the results. However, this works in our favor in that the total effect of the revision to the leniency policy becomes more negative and significant, strengthening our initial findings. The parameter estimates for predicted difference in R&D become significant in all telecommunications specifications.

Second, we reran our across industry sample regressions (presented in Table 3) for a more narrow definition of the market, defined at the 6-digit NAICS level rather than the 3-digit level. Third, we tested the sensitivity of our results to our RJV end-date assumption by "ending" the RJV five years after the last entrant entered (rather than ending the RJV in the last year an entrant joined). We chose five years because we never observe another firm joining any RJV five years after the last firm added. For both of these robustness checks our results do not change.

Finally, the results presented in Tables 3 and 4 address potential serial correlation in the errors by clustering and bootstrapping. An alternative way to limit the effects of potential serial correlation is to run the regressions in a tighter window around the leniency policy. We reran the regressions using data from 1991 to 1996. The results from this robustness check do not change in sign or significance, although the total effect of the leniency policy revision is smaller in magnitude in the across industry sample specifications.

6 Conclusion

Many empirical papers focus on the benefits of research joint ventures. In this paper, we observe that many firms who are rivals in the product market, undertake cooperative R&D activities via research joint ventures. It is possible that permitting firms to legally collude in R&D may facilitate illegal collusion in the final goods market. If this is the case, firms may undertake RJVs for anticompetitive reasons with possible negative social welfare repercussions.[53] The question of whether collusive intensions may be facilitated by RJVs has not been addressed in the empirical literature, and this paper fills this gap.

We examine RJVs across all industries and in telecommunications markets in detail. To separately identify the intention to collude from other (legal) reasons to form an RJV we take advantage of a shift in antitrust policy which made product market collusion more difficult to sustain. Specifically, we exploit the variation in RJV formation generated by a quasi-experiment via the leniency policy that effects the collusive benefits of an RJV while not directly affecting the research synergies associated with that venture. We find that the leniency policy revision has a significant negative effect on the probability of joining an RJV, which is consistent across market definitions, model specifications, and robust to a variety of modifications. Specifically, our results show that the shift in antitrust policy reduces the probability a firm interested in telecommunications research joins an RJV by 25%. Furthermore, the higher the market power of the RJV, the more an impact the leniency policy has on the decision to join an RJV. Our results are consistent with collusive behavior on the part of telecommunications firms, particularly over the years of telecommunications regulation. To the extent that antitrust authorities wish to detect and prohibit collusion brought about through RJV formation, our results suggest they should be more concerned when RJVs have a high joint market share relative to industry concentration.

[53] The potential benefits to R&D collaboration are many. Hence, the impact on social welfare of this potentially collusive behavior in the product market is not obvious. Whether welfare is lowered as a result of collusion among RJV members depends, of course, on the magnitude of the welfare loss due to product market collusion relative to the welfare gain due to R&D collaboration.

References

"d'Aspremont, C. and A. Jacquemin (1988) "Cooperative and Noncooperative R&D in Duopoly with Spillovers," *American Economic Review*, 78(5): 1133-1137.

Berg, S.V., Duncan, J., and P. Friedman (1982) *Joint Venture Strategies and Corporate Innovation*, Cambridge: Oelgeschlager Gunn & Hain.

Bertrand, M., E. Duflo, and S. Mullainathan (2004) "How Much Should We Trust Difference-in-Difference Estimates?" *Quarterly Journal of Economics*, 119(1): 249-275.

Bloch, F. (1995) "Endogenous Structures of Association in Oligopolies," *Rand Journal of Economics*, 26(3): 537-56.

Brodley, J. (1990) "Antitrust Law and Innovation Cooperation," *Journal of Economic Perspectives*, 4(3): 97-112.

Brown, N. and J. Burns (2000) "Antitrust Violations," *American Criminal Law Review* 37:163-203.

Caloghirou Y. and N.S. Vonortas (2000) "Science and Technology Policies Towards Research Joint Ventures," Final Report, Project SoE1-CT97-1075,TSER, European Commission, DG XII.

Cameron, A.C., Gelbach, J., and D. Miller (2007) "Bootstrap-Based Improvements for Inference with Clustered Errors," forthcoming, *Review of Economics and Statistics*.

Cassiman, B. and R. Veugelers (2002) "R&D Cooperations and Spillovers: Some Empirical Evidence from Belgium," *American Economic Review*, 92(4): 1169-1184.

Conner, J. (2001) Global Price Fixing. Boston Mass: Kluwer Academic Publishers

Cooper, R. and T. Ross (2007) "Sustaining Cooperation with Joint Ventures," *Journal of Law, Economics, and Organization,*

Jorde, M. and D. Teece (1990) "Innovation and Cooperation: Implications for Competition and Antitrust," *Journal of Economic Perspectives*, 4(3): 75-96.

Greene, W. (2000) Econometric Analysis, 4th ed., Prentice Hall, Engelwood Cliffs.

Greenlee, P. and B. Cassiman (1999) "Product Market Objectives and the Formation of Research Joint Ventures." *Managerial and Decision Economics*, 20: 115-130.

Hagedoorn, J., A.N. Link, N.S. Vonortas (2000) "Research Partnerships," *Research Policy*, 29(4-5).

Hernan, R., P.L. Marin, and G. Siotis (2003) "An Empirical Analysis of the Determinants of Research Joint Venture Formation," *Journal of Industrial Economics*, 51: 75-89.

Huber, P., M. Kellogg, and J. Thorne (1992). "The Geodesic Network II: 1992 Report on Competition in the Telephone Industry," Geodesic Co., Washington D.C.

Kaiser, U. (2002) "An Empirical Test of Models Explaining Research Expenditures and Research Cooperation: Evidence for the German Service Sector," *International Journal of Industrial Organization*, 20:747-74.

Kobayashi, B. (2001) "Antitrust, Agency, and Amnesty: An Economic Analysis of the Criminal Enforcement of the Antitrust Laws Against Corporations," *George Washington Law Review* 69(5/6):715-744.

Lee, L.F. (1978) "Unionism and Wage Rates: A Simultaneous Equations Model with Qualitative and Limited Dependent Variables," *International Economic Review*, 19(2): 415-433.

Link, A. (1996) "Research Joint Ventures: Patterns from *Federal Register* Filings," *Review of Industrial Organization*, 11(5): 617-628.

Link, A., and L. Bauer (1989) "Cooperative Research in US Manufacturing."

MacAvoy, P.W. (1995) "Tacit Collusion under Regulation in the Pricing of Interstate Long-Distance Telephone Services," *Journal of Economics and Management Strategy* 4:147-185.

Majewski, S. and D. Williamson (2002) "Endogenous Spillovers, Strategic Blocking, and the Design of Contracts in Collaborative R&D: Evidence from the NCRA Filings of R&D Joint Ventures," Antitrust Division, US Department of Justice, Economic Analysis Group working paper.

Manski, C., and D. McFadden (1981) "Alternative Estimators and Sample Designs for Discrete Choice Analysis," in *Structural Analysis of Discrete Data*. Editors C.F. Manski and D. McFadden. Cambridge, Mass. MIT Press.

Marin, P.L. Siotis, G. and R. Hernan (2003) "An Empirical Evaluation of the Determinants of Research Joint Venture Formation," *Journal of Industrial Economics* 51(1): 75-89.

Martin, S. (1995) "R&D Joint Ventures and Tacit Product Market Collusion," *European Journal of Political Economy* 11:733-41.

Nevo, Aviv (2000) "'Mergers with Differentiated Products: The Case of the Ready-to-Eat Cereal Industry," *Rand Journal of Economics* 31(3): 395-421.

Oum, T.H., and J.H. Park (1997) "Airline Alliances: Current Status, Policy Issues, and Future Directions," *Journal of Air Transport Management* 3: 133-44.

Pittman R., and G. Werden (1990) "The Divergence of SIC Industries from Antitrust Markets: Indications from Justice Department Merger Cases," *Economics Letters*, 33: 283-286.

Reinganum, J. (1983) "Uncertain Innovation and the Persistence of Monopoly," *American Economic Review*, 73(4): 741-748.

Roller, L.H., Siebert R., and M. Tombak (2007) "Why Firms Form (or do not Form) RJVS," *Economic Journal* 117(522):1122-1144.

Scott, John T. (1988) "Diversification versus Cooperation in R&D Investment," *Managerial Decision Economics*, 9: 173-86.

Scott, John T. (1993) *Purposive Diversification and Economic Performance*, New York: Cambridge University Press.

Shapiro, C., and R.D. Willig (1990) "On the Antitrust Treatment of Production Joint Ventures." *Journal of Economic Perspectives*, 4(3): 113-130.

Spagnolo (2000) "Self defeating antitrust laws: how leniency programs solve bertrand's paradox and enforce collusion in auctions," mimeo, Stockholm school of economics.

Spratling, G. (1999) "Negotiating the Waters of International Cartel Prosecutions," Address to the Thirteenth Annual National Institute on White Collar Crime. www.usdoj.gov/atr/publi/speeches/2275.htm

Werden, G (1988) "The Divergence of SIC Industries from Antitrust Markets: Some Evidence from Price Fixing Cases" *Economics Letters*, 28: 193-197.

Wilson, J. (1975) "Market Structure and Interfirm Integration in the Petroleum Industry," *Journal of Economic Issues*, 9: 319-35.

Yi, S. (1995) "R&D Cooperation, Product-Market Collusion and Welfare." Working Paper, Dartmouth College.

Yi, S.S., and H. Shin (2000) "Endogenous Formation of Research Coalitions with Spillovers," *International Journal of Industrial Organization* 18:229-56.