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## **An Econometric Analysis of Trends in Research Joint Venture Activity**

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# **An Econometric Analysis of Trends in Research Joint Venture Activity**

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**A. Link, D. Paton and D. Siegel**

## **Abstract**

We estimate an econometric model of the propensity of firms to engage in research joint ventures (RJVs), in order to explain the recent precipitous decline in RJVs filed with the U.S. Department of Justice. We find that RJV activity is inversely related to the competitive position of U.S. firms in global high-technology industries and that the establishment of the U.S. Commerce Department's Advanced Technology Program (ATP) induced a structural change in the propensity of firms to engage in RJVs. Thus, two factors may explain the recent downturn in RJV filings: a substantial improvement in U.S. global performance in high-technology markets and a sharp decline in ATP funding.

## **Outline**

1. Introduction
2. Econometric Model
3. Empirical Results
4. Interpretation of Results and Conclusions

## **Non-Technical Summary**

This paper examines the antecedents and consequences of the National Cooperative Research Act (NCRA) of 1984. The NCRA established a system whereby U.S. firms can file research joint ventures (RJVs) with the U.S. Department of Justice and reduce their exposure to antitrust litigation. The number of RJVs increased virtually monotonically until 1995 and has declined virtually monotonically since then.

In an effort to understand the causes of this precipitous decline, we specify a time series econometric model of RJV filings. We hypothesize that the propensity of firms to file RJVs is related to the intensity of global competition in high technology industries, the percentage of industry-funded R&D devoted to development (as opposed to basic or applied research), a proxy for the business cycle, and merger and acquisitions (M&A) activity.

Using the NSF CORE database, which consists of the complete universe of RJV filings with the Department of Justice for the years 1985-1998, we estimate several variants of our econometric model. We also conduct a series of tests of the structural stability of these regressions, in response to three events that may have induced a structural shift in the propensity of firms to sponsor RJVs. One such event was the election of Bill Clinton in November 1992, which may have signaled stricter enforcement of antitrust policy and encouraged firms to seek protection from potential litigation with regard to RJVs. Two policy initiatives relating to RJVs were also implemented during the sample period. These were the establishment and growth of the U.S. Commerce Department's Advanced Technology Program (ATP), which began in 1990, and the National Cooperative Research and Production Act (NCRPA) of 1993, which was an extension of the NCRA.

In conducting our structural stability analysis, we employed the Brown, Durbin, and Evans [1975] test, which does not require prior information concerning the true point of structural change, unlike the standard Chow and Wald tests. Brown-Durbin-Evans tests have been used to analyze the structural stability of the demand for money (Heller and Khan (1979)), aggregate output fluctuations (McConnell and Perez-Quiros (2000)), stability of sales tax revenue (Anders, Siegel, and Yacoub (1998)), and returns to R&D (Lichtenberg and Siegel (1991)).

Our econometric estimates reveal an inverse relationship between RJV activity and the competitive position of U.S. firms in global high-technology industries. The structural stability tests indicate that the establishment of the ATP may have caused a structural shift in the propensity of firms to sponsor RJVs. Taken together, these findings imply that two factors may explain the recent downturn in RJV filings: the recent dramatic improvement in the global market share of U.S. firms in high-technology industries (from 29.2 percent in 1994 to 37.5 percent in 1998) and a precipitous decline in funding for the ATP (from \$512 million in 1995 to \$212 million in 1998). Our results also imply that public funding of R&D (e.g., ATP) may stimulate firms to engage in additional collaborative research projects. This is a spillover mechanism that warrants further attention as national innovation systems evolve.

## I. Introduction

In the early 1980s, there was growing concern in the United States regarding the pervasive slowdown in productivity growth and the concomitant decline in the global competitiveness of American firms in key high technology industries. One of the alleged culprits of the downturn in economic performance was a decline in the rate of technological innovation. As noted in a November 18, 1983, House report concerning the proposed Research and Development Joint Ventures Act of 1983 (HR 4043):

The United States, only a decade ago, with only five percent of the world's population, was generating about 75 percent of the world's technology. Now, the U.S. share has declined to about 50 percent and in another ten years ... it may be down to only 30 percent. ... The encouragement and fostering of joint research and development ventures are needed responses to the problem of declining U.S. productivity and international competitiveness.

In an April 6, 1984, House report on the Joint Research and Development Act of 1984 (HR 5041), the alleged benefits of joint research and development were clearly articulated for the first time:

Joint research and development, as our foreign competitors have learned, can be procompetitive. It can reduce duplication, promote the efficient use of scarce technical personnel, and help to achieve desirable economies of scale. ... [W]e must ensure to our U.S. industries the same economic opportunities as our competitors, to engage in joint research and development, if we are to compete in the world market and retain jobs in this country.

The National Cooperative Research Act (NCRA) was subsequently enacted on October 11, 1984 (PL 98-462) "to promote research and development, encourage innovation, stimulate trade, and make necessary and appropriate modifications in the operation of the antitrust laws."<sup>1</sup> The NCRA established a registration process, later expanded by the National Cooperative Research and Production Act (NCRPA) of 1993 (PL 103-42), under which firms wishing to engage in research joint ventures (RJVs) can disclose their research intentions to the Department of Justice.<sup>2</sup> Firms generate two major benefits from such voluntary filings: (i) if subjected to criminal or civil action they are evaluated under a rule of reason that determines

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<sup>1</sup> This purpose is stated as a preamble to the Act. For an historical perspective on the NCRA see Scott (1989).

<sup>2</sup> We use the term RJV to refer to a collaborative research arrangement through which firms jointly acquire technical knowledge. This usage of the term RJV is more general than employed in the theoretical literature. See, for example, Kamien, Muller, and Zang (1992) and Combs (1993).

whether the venture improves social welfare; and (ii) if found to fail a rule-of-reason analysis, they are subject to actual rather than treble damages.<sup>3</sup>

As shown in Figure 1, the number of firms filing RJVs with the Department of Justice increased virtually monotonically from the inception of the NCRA through 1995, and has since declined precipitously. There are several alternative interpretations of this trend. One interpretation is that the incentives embodied in the NCRA are no longer sufficient to stimulate the formation of joint research projects. Another explanation of the decline in RJVs is that U.S. firms have experienced difficulties managing collaborative research and thus, have abandoned such alliances. Finally, it might also signify that RJVs are no longer an effective organizational form.

The purpose of this paper is to understand the underlying economic rationale for the decline in the incidence of RJVs. To accomplish this objective, we outline and estimate a time series econometric model of the propensity of firms to file RJVs. Our framework also provides some insights regarding related complementary policy initiatives that were designed to promote cooperative research.

The remainder of this paper is organized as follows. Section II describes the econometric model. Empirical results are presented in Section III. The concluding section of the paper discusses the implications of our findings.

## **II. Econometric Model**

We hypothesize that there are several key determinants of the propensity of firms to disclose their intentions to engage in collaborative research. First, firms may participate in collaborative research projects as a strategic response to competitive pressures from abroad. Specifically, when high-technology firms encounter enhanced global competition they may be more inclined to develop partnerships with domestic rivals who are facing a similar global

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<sup>3</sup> Filing with the Department of Justice is distinct from the decision of whether to form an RJV in the first place. For a theoretical analysis of the formation decision, see, for example, Katz (1986). Economic theory always applies a rule-of-reason approach to antitrust issues. One of the primary focuses of the theoretical literature on cooperative R&D agreements has been to identify the conditions under which an RJV will be welfare enhancing. For a review of this literature, see Hagedoorn, Link and Vonortas (2000). However, the theoretical literature does not address the private decision of whether to file with the Department of Justice, that is to announce publicly the formation of the RJV, and to then have that filing made public through publication in the *Federal Register*.

threat. Such alliances can enable companies to reduce innovation costs and accelerate the rate of product or process development.<sup>4</sup> Also, when U.S. firms are experiencing such competitive pressure, they might assume that the federal government will be much less aggressive in pursuing antitrust violations. Indeed, as noted earlier, government authorities explicitly mentioned a desire to relax antitrust enforcement regarding collaborative R&D in the enabling NCRA legislation. Thus, we conjecture that there is an inverse relationship between the global competitive position of U.S. high-technology firms and their propensity to file RJVs.

We also hypothesize that firms may participate in RJVs as a substitute for internal research projects. Economic theory predicts that firms have a stronger incentive to collaborate when the nature of the research is closer to basic, as opposed to the development end of the R&D spectrum.<sup>5</sup> Furthermore, the greater risk and uncertainty associated with basic research provides an additional incentive for firms to collaborate on research projects. Thus, we expect to observe a positive relationship between the percentage of R&D expenditure that is allocated to development and the likelihood of engaging in cooperative research ventures.

We also hypothesize that the propensity of firms to participate in RJVs is related to overall economic conditions. Specifically, we expect that such R&D investments are counter-cyclical. That is, when the economy is weak, firms may lack sufficient internal resources to finance long-term R&D projects. In such situations, they may be more likely to rely on cooperative research arrangements to generate new technical knowledge. Alternatively, when economic conditions are favorable, they may use profits or retained earnings as a cushion to support internal research projects. Thus, we anticipate observing an inverse relationship between proxies for the business cycle and RJV activity.<sup>6</sup>

Lastly, there is also the possibility that firms may use mergers and acquisitions (M&A) as a substitute for formal RJVs, particularly when the proposed research partner is small and in need of complementary assets (e.g., marketing and distribution) to successfully commercialize

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<sup>4</sup> See Hagedoorn, Link, and Vonortas (2000) for a review of this theoretical literature.

<sup>5</sup> See Link and Bauer (1989) for a theoretical explanation.

<sup>6</sup> Relatedly, Ghosal and Gallo (2001) show that antitrust enforcement by the Department of Justice is counter-cyclical. This finding complements our argument that firms are more likely to disclose their collaborative research intentions when the economy turns down.

an innovation that arises from the research project.<sup>7</sup> Relatedly, it is conceivable that companies who have engaged in RJVs, in the aftermath of NCRA or other initiatives to promote collaborative R&D, may develop long-lasting relationships with their research partners. At some point, they may wish to permanently internalize these relationships. If mergers and acquisitions do indeed constitute an alternative to RJVs, we would expect to observe an inverse relationship between RJVs and M&A activity.

Based on the preceding discussion, the propensity to file an RJV can be expressed as:

$$(1) \quad RJV = f(TECHCOMP, DEVINT, BCYC, M\&A, \mathbf{Z}) = f(\mathbf{X})$$

where *TECHCOMP* is a proxy for the competitive position of U.S. high-technology firms in global markets, *DEVINT* refers to the percentage of industry-funded R&D devoted to development activity (the “D” of R&D), *BCYC* is a proxy for the business cycle, *M&A* represents the number of mergers and acquisitions, and  $\mathbf{Z}$  denotes a vector of additional control variables.

More specifically, we estimate the following time series econometric model:

$$(2) \quad RJV_t = \beta_0 + \beta_1 TECHCOMP_t + \beta_2 DEVINT_t + \beta_3 BCYC_t + \beta_4 M\&A + \beta_5 DGOV1 + \beta_6 DGOV2 + \varepsilon_t$$

where  $\varepsilon_t$  is a disturbance term.

Definitions of the variables in equation (2) are provided in Table 1. Two dummy variables have been added to equation (2) to control for institutional anomalies that affected the processing of RJV disclosures by federal officials: a temporary closure in the unit of the Department of Justice that is responsible for *Federal Register* notices of disclosure (*DGOV1*) and a temporary furlough of government employees that also interrupted the filing of disclosure notices (*DGOV2*).

Note also that our dependent variable, *RJV*, is a count variable—the number of new RJVs disclosed in the *Federal Register* each month. Thus, we considered a Poisson and a negative

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<sup>7</sup> See Link (1988) for preliminary evidence on this.



binomial (NB), or generalized Poisson, specification of equation (1).<sup>8</sup> The basic Poisson model as applied to RJV filings is:

$$(3) \quad \Pr(y) = \frac{\exp(-\lambda) \lambda^y}{y!}$$

where  $y = RJV$  and  $\ln(\lambda) = f(\mathbf{X})$ , the deterministic function of  $\mathbf{X}$  from equation (1). The Poisson distribution has the following property:  $E(y) = \text{Var}(y) = \lambda$ , conditional on  $\mathbf{X}$ . This restrictive distributional assumption is relaxed in the NB distribution, which allows  $\text{Var}(y) > E(y)$ , the property known as “over-dispersion” or “extra-Poisson variation.” The NB specification generalizes  $\lambda$  to be distributed as a Gamma random variable with parameters  $e^{f(x)}$  and a shape parameter  $\alpha$ . As shown in Winkelmann and Zimmerman (1995), the resulting likelihood function for  $y$  is:

$$(4) \quad L(y) = \binom{\delta + y - 1}{y} p^\delta (1 - p)^y$$

where  $\delta = 1/\alpha$  and  $p = (1 + \alpha(\exp^{f(x)}))^{-1}$ . The Poisson distribution (and hence the property of no over-dispersion) corresponds to the special case of  $\alpha = 0$ . For each NB regression, we computed the  $\chi^2$  statistic (with one degree of freedom) for the test of the null hypothesis that  $\alpha = 0$ ; that is, that the data are distributed as Poisson (conditional on  $\mathbf{X}$ ). Since we can reject this restriction in each case, we report only the NB estimates of variants of equation (2).<sup>9</sup>

### III. Empirical Results

A potentially important econometric concern in any time series regression is whether the variables are stationary. Unfortunately, it is not clear from the literature whether standard tests for stationarity apply with count data, as opposed to a continuous variable. This lack of clarity in the literature precludes a formal treatment of this issue here. However, as shown in Table 2, standard stationarity tests suggest that the key variables in our model: the dependent variable

<sup>8</sup> See Hausman, Hall, and Griliches (1984).

<sup>9</sup> All results are available from the authors upon request.

(*RJV*) and the proxy for the global competitiveness of U.S. firms (*TECHCOMP*) are both stationary.

Our method is to use information criteria to establish the appropriate lag order for the tests. The criteria we use are the Akaike Information Criteria and the Schwarz Information Criteria. As discussed in Patterson (2000), there is some evidence to suggest that the Akaike Information Criteria tends to over-parametrize the model, so a lag structure based on the Schwarz Information Criteria may be more appropriate. For *RJV*, we also conducted a Philips-Perron (1988) test, assuming a lag order of 9, yielding a test statistic of  $-10.322$ , which is significant at the .01 level. Although we cannot reject non-stationarity for the other independent variables, tests on the residuals from OLS estimation of the model provide informal evidence in favor of cointegration. The fact that our base econometric results are robust to alternative lag structures provides additional support for this conclusion, so we proceed with conventional estimation procedures.

Negative binomial parameter estimates of equation (2) are presented in Table 3. Each independent variable is constructed as a weighted average of the current and previous year's values, although alternative lag structures were used and the findings do not differ significantly from the findings presented here.<sup>10</sup> We also report the  $\chi^2$  statistic for the test of the null hypothesis that the data are distributed as Poisson, which is decisively rejected.

Several findings emerge from this table. Consistent with our expectations, the coefficient on *TECHCOMP* is negative and significant. That is, there appears to be an inverse relationship between a proxy for the competitiveness of U.S. firms in global high-technology industries and the formation of *RJVs*. We also find a positive association between the percentage of R&D devoted to development (*DEVINT*) and *RJVs*. This result is consistent with our notion that collaborative research projects constitute a substitute for internal basic research projects. Contrary to our expectations, a positive and significant coefficient on our proxy for the business cycle (*BCYC*) implies that *RJV* filings are actually procyclical. However, a negative and significant coefficient on *M&A* appears to confirm our conjecture of a negative association between mergers and acquisitions and *RJVs*.

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<sup>10</sup> The results from alternative lag structures are available from the authors upon request.

Next, we assess the structural stability of the parameter estimates of the regression equation, in light of three exogenous events. These events occurred during the sample period, and could have induced a structural change in the propensity of firms to disclose their RJV activities. One event was the election of President Clinton in November 1992, which signified a change from Republican to Democratic control of the Department of Justice. Democrats have historically been more aggressive in antitrust enforcement than Republicans; Clinton's election may have signaled to industry a stricter enforcement of antitrust policy and thus, encouraged firms to seek protection from potential litigation with regard to their involvement in collaborative research ventures.

In addition to the change in administration, two relevant policy interventions relating to RJV formations also occurred during the sample period. The U.S. Commerce Department's Advanced Technology Program (ATP) was established as part of the Omnibus Trade and Competitiveness Act of 1988 (PL 100-418). Its key goals are:

[T]o assist U.S. businesses to improve their competitive position and promote U.S. economic growth by accelerating the development of a variety of pre-competitive generic technologies by means of grants and cooperative agreements.

The ATP received its initial funding in 1990 and announced its initial awards in March 1991. A second initiative to promote collaborative research was the aforementioned NCRPA of 1993, which broadened the scope of the NCRA to include joint research and production ventures.

To test whether these three events induced a structural change in equation (2), we considered several stability tests. The usual practice in assessing the constancy of regression coefficients over time is to impose on the equation prior information concerning the event that is hypothesized to cause the structural change. The researcher then either estimates separate regressions, given this assumed breakpoint, or a single equation with dummy variables. The most popular test for structural change is the Chow test. One problem with the Chow test is that it requires the assumption that the disturbance variance is the same in both regressions. As a result, a new generation of tests of structural change (Ghysels, Guay, and Hall (1997)) are typically based on the composition of Wald, likelihood ratio (LR), and Lagrange-multiplier-type (LM) tests, which do not require such restrictive assumptions. The most commonly used

of these is the Wald test, which Bai and Perron (1998) have shown can be used to identify multiple structural changes.

In contrast to the Chow and Wald tests, the Brown, Durbin, and Evans (BDE, 1975) test for the structural stability of regression parameters does not require prior information concerning the true point of structural change. Under this method, an analysis of the cumulative sum of squared residuals (CUSUMSQ) from the regression determines where, if at all, a structural break or shift occurs. Thus, an attractive property of the BDE CUSUMSQ test is that it allows the data to identify when the true point of structural change occurs.<sup>11</sup>

The basic intuition underlying the BDE test is that if the structure of the regression equation varies according to an index, time in this case, the residuals will shift, compared to the constant coefficients model. The BDE test uses the test statistic  $S_r$ , which is derived from the normalized cumulative sum of squared residuals from a recursive estimation model:

$$(5) \quad S_r = \left[ \frac{\sum_{k+1}^r w_i^2}{\sum_{k+1}^N w_i^2} \right] \quad r = k + 1, \dots, N$$

where  $w_i$  are the orthogonalized recursive residuals,  $k$  is the number of regressors, and  $N$  is the number of observations.  $S_r$  has a beta distribution with expected value,  $\mu = (r-k) / (N-k)$ . With constant coefficients, a graph of  $S_r$  will coincide with its mean-value line, within a confidence interval ( $\pm C_0 + (r+k) / (N-k)$ ), where  $C_0$  is Pyke's modified Kolmogorov-Smirnov statistic. The actual and expected value of the test statistic,  $S_r$  and  $E(S_r)$  can be calculated, for each observation. The absolute value of the difference between  $S_r$  and  $E(S_r)$  is also computed. If the regression coefficients do not vary over time, then these differences will fall within the specified confidence region. When the value of  $(S_r - E(S_r))$  exceeds  $C_0$ , we have identified a point where structural change has occurred.<sup>12</sup>

As illustrated in Figure 2, a plot of the Kolmogorov-Smirnov test statistic reveals that the structure of equation (2) is not stable. It appears as though a statistically significant structural

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<sup>11</sup> These tests have been employed on time series and cross-sectional data to analyze the stability of such economic phenomena as the demand for money (Heller and Khan 1979), aggregate output fluctuations (McConnell and Perez-Quiros 2000), returns to R&D investment (Link 1980), and sales tax revenue (Anders, Siegel, and Yacoub 1998).

break (at a 5% level of significance) occurred in December 1991. Based on our *a priori* judgment of events that could induce a structural change in the propensity to disclose joint venture intentions, only the creation of the ATP occurred prior to December 1991. In fact, awards from ATP's first solicitation were made in March 1991, and a second solicitation was announced in September 1991.

To assess the economic effects of this ATP-induced structural shift, we estimated two new variants of the econometric model. In the first variant of the model, we defined a dummy variable, *DATP*, which is 0 from March 1985 through December 1991, and 1 thereafter. We then interacted the ATP dummy with the variables *TECHCOMP* and *DEVINT*. These findings are reported in column (1) of Table 4. Note that the coefficient on the interaction of *TECHCOMP* and the ATP dummy is negative and significant. The magnitude of the interaction effect (-0.764) is much stronger than the marginal effect of *TECHCOMP* (-0.043). This result suggests that the activities of the ATP have significantly enhanced the responsiveness of firms to competitive pressures in high technology industries. We also observe that once we control for the effect of the ATP, the previously captured substitution effect from in-house research to collaborative research and the cyclical effect are no longer significant. If we estimate the model without the interaction term between *DEVINT* and *DATP* (not shown on the table), the coefficient on *M&A* is negative and significant, while the coefficient on *DAPT* is strongly positive and significant. The latter result suggests that the ATP has an absolute positive effect on RJV disclosures, *ceteris paribus*.

In the second new variant, we split the sample in December 1991, based on the BDE CUSUMSQ test statistic indicating a structural change during that month, and re-estimated equation (2) separately for each time period. These findings are reported in columns (2) and (3) of Table 4. In both periods, we find that the coefficient on *TECHCOMP* is negative and significant, confirming our earlier result regarding RJVs a strategic response to global competition in high technology industries. However, the magnitude of this effect is again significantly greater in the post-ATP period.<sup>13</sup> Note, however, that splitting the sample appears to weaken our earlier findings regarding the responsiveness of RJVs to the intensity of R&D

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<sup>12</sup> An alternative, summary test of structural stability, which is also based on the cumulative sum of residuals, is suggested by Hansen (1992).

devoted to development and the business cycle. Indeed, we find that that the only other statistically significant determinant of RJV filings is *M&A*, but this result holds only for the pre-ATP period.

#### **IV. Interpretation of Results and Conclusions**

Our empirical evidence sheds some light on possible causes of the precipitous decline in RJVs since 1995. At first glance, it appears that this downturn could be an indication that the National Cooperative Research Act of 1984 has reached the limits of its effectiveness, in terms of eliciting new RJVs. However, our econometric analysis suggests that the Act is indeed fulfilling one of its intentions, namely to provide an innovation-friendly environment for firms to respond to global competition in high-technology industries. In each variant of the model, we found an inverse relationship between global competitiveness in high-technology markets and the propensity of U.S. firms to engage in collaborative research projects. In this regard, it appears that RJVs constitute an effective organizational form to enhance innovative activity.

More importantly, our empirical evidence suggests that two factors might explain the recent downturn in RJV filings: a substantial improvement in the global performance of U.S. firms in high-technology industries and a precipitous decline in funding for the ATP. According to the National Science Foundation (National Science Board 2000), the global market share of U.S. firms in high-technology industries increased from 29.2 percent in 1994 to 37.5 percent in 1998. The U.S. Commerce Department reports that the budget for the ATP declined from a peak of \$512 million in 1995 to \$212 million in 1998.

Our finding that a structural change in the regression equation occurs soon after the establishment of the ATP has several interpretations, which are all consistent with the notion that the ATP stimulated the formation of additional RJVs. First, since one mission of the ATP is to encourage cooperative research activity, our findings imply that it is succeeding in that regard. Second, the establishment of the ATP may have provided a signal to firms that Congress and the Administration will support collaborative research relationships even beyond the legislated protection afforded RJVs under the NCRA. And third, there is a growing body of case-based evidence that suggests additionality, namely that firms that receive ATP support

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<sup>13</sup> The difference in the pre- and post-ATP coefficients on *TECHCOMP* is significant at the .05 level.

for collaborative research are more likely to engage on their own in additional collaborative activities (Feldman and Kelley forthcoming, Link 1996).<sup>14</sup>

Several caveats to our empirical findings should be noted. First, *RJV* is a count variable, and not a measure of the resources devoted to these endeavors. Unfortunately, data on the resources devoted to an *RJV* are not available. Furthermore, it would be useful to have outcome or performance measures for each *RJV*, but again such information is not available. Also, it might be worthwhile to examine the underlying heterogeneity that is currently masked in our aggregate analysis. For example, some *RJVs* are oriented toward process innovation while others are aimed at product innovations. The nature of the technologies and the time frame of the research projects will also differ. We hope that this paper will stimulate further research on the impact of policy initiatives, such as ATP, on the propensity of firms to engage in collaborative research projects. This is an important aspect of policy-induced spillovers that has not attracted much attention in the literature.

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<sup>14</sup> This spillover effect is also discussed in Audretsch and Feldman (1996) and Audretsch and Stephan (1996).

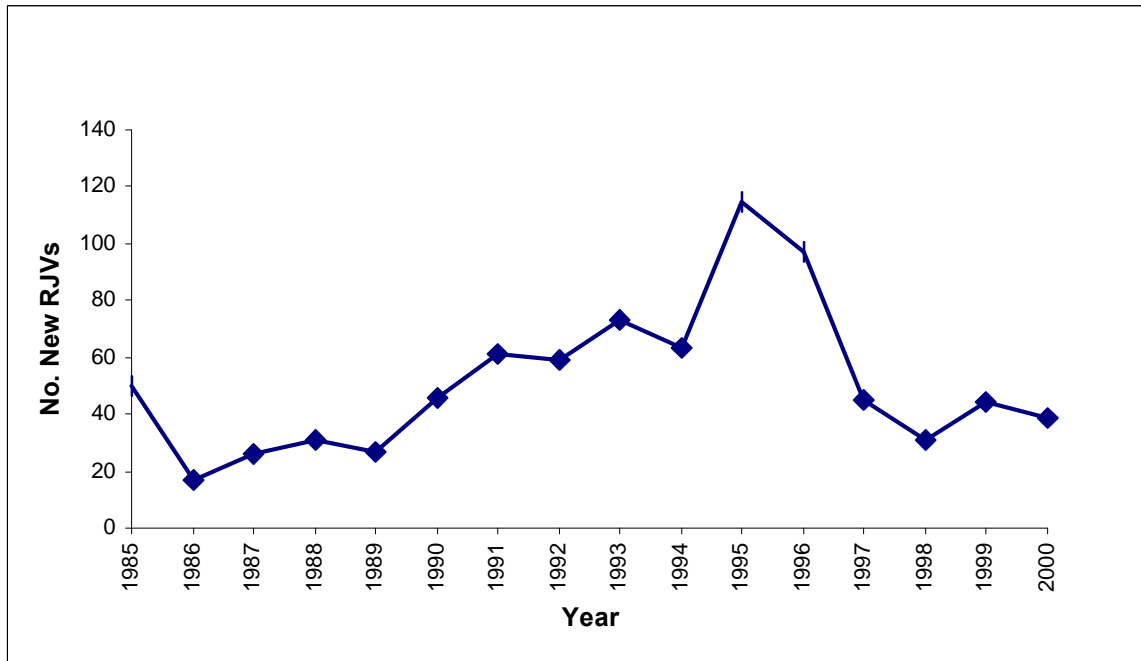
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**Figure 1**  
**Annual Counts of New Research Joint Ventures, 1985-2000**



**Source:** CORE database (National Science Board 2000).

**Notes:** Data are available in the CORE database through 2000; however, our econometric analysis is from 1985-1998, due to a lack of data after 1998 on several independent variables.

**Table 1**  
**Variable Definitions**

Variable	Definition	Data Source
<i>RJV</i>	Monthly Number of RJVs filed with the U.S. Department of Justice, 1985-1998 *	NSF CORE database (National Science Board 2000).
<i>TECHCOMP</i>	U.S. Trade Balance in Advanced Technology Products, monthly, 1985-1998	U.S. Department of Commerce, <i>U.S. Trade with Advanced Technology</i> (see McGuckin et al. 1989).
<i>DEVINT</i>	Annual Percentage of Industry-Funded R&D Allocated to Development, 1985-1998	National Science Board, <i>Science &amp; Engineering Indicators 2000</i> , Tables A2-6 and A2-17 and unpublished data from NSF
<i>BCYC</i>	12 month Weighted Average of U.S. Industrial Production Index, (1992=100), seasonally adjusted, quarterly, 1985-1998.	Board of Governors, <i>Federal Reserve Bulletin</i> , monthly.
<i>M&amp;A</i>	Annual Number of U.S. Mergers and Acquisitions, 1985-1998	Thomson Financial Securities Data, Mergers & Corporate Transactions Database
<i>DGOV1</i>	=1 July 1995 to November 1995; 0 otherwise	Interviews with Pre-Merger group at Department of Justice
<i>DGOV2</i>	=1 in December 1995 and January 1996; 0 otherwise	Interviews with Pre-Merger group at Department of Justice

**Notes:** \*Data are available on RJVs in the CORE database on the day that the RJV was noticed in the *Federal Register*. These data are then aggregated by month. In January 1985 7 RJVs were filed, in February 1985 22 were filed, and in March 1985 and thereafter for the next several years the monthly totals averaged 5 per month. The 22 filings in February 1985 were the second most over the 14-year period; there were 24 filings in December 1995 just after the pre-merger group in the Department of Justice completed its reorganization and just before the federal government furloughed employees for a month. We interpret January and February 1985 as “blips” in the sense that February represents an accumulation of pre-1985 collaborative activity that was filed in early January 1985 after the passage of the NCRA and noticed in the *Federal Register* in February 1985. We delete these two months from our time series, and thus our analysis has 166 observations. We control for the Department of Justice reorganization and government furlough periods with *DGOV1* and *DGOV2*.

**Table 2**  
**Stationarity Tests for the Variables in the RJV Model**

<b>Unit Root Tests</b>				
	<b>Akaike Information Criteria</b>		<b>Schwarz Information Criteria</b>	
<b>Variable</b>	<b>Lag</b>	<b>Augmented Dickey-Fuller Test</b>	<b>Lag</b>	<b>Augmented Dickey-Fuller Test</b>
<i>RJV</i>	9	-1.743	1	5.219*
<i>TECHCOMP</i>	12	-3.321**	1	-2.627***
<i>DEVINT</i>	11	-1.418	12	-1.208
<i>BCYC</i>	1	2.47	1	2.47
<i>M&amp;A</i>	9	1.61	11	2.70

**Notes:**

\* indicates that the null hypothesis of a unit root is rejected at the .01 level; \*\* .05 level; \*\*\* .10 level.  
Lags are chosen on the basis of the Akaike Information Criteria or the Schwarz Information Criteria.

**Table 3**  
**Negative Binomial Parameter Estimates of the Propensity to File RJVs (Equation (2))**

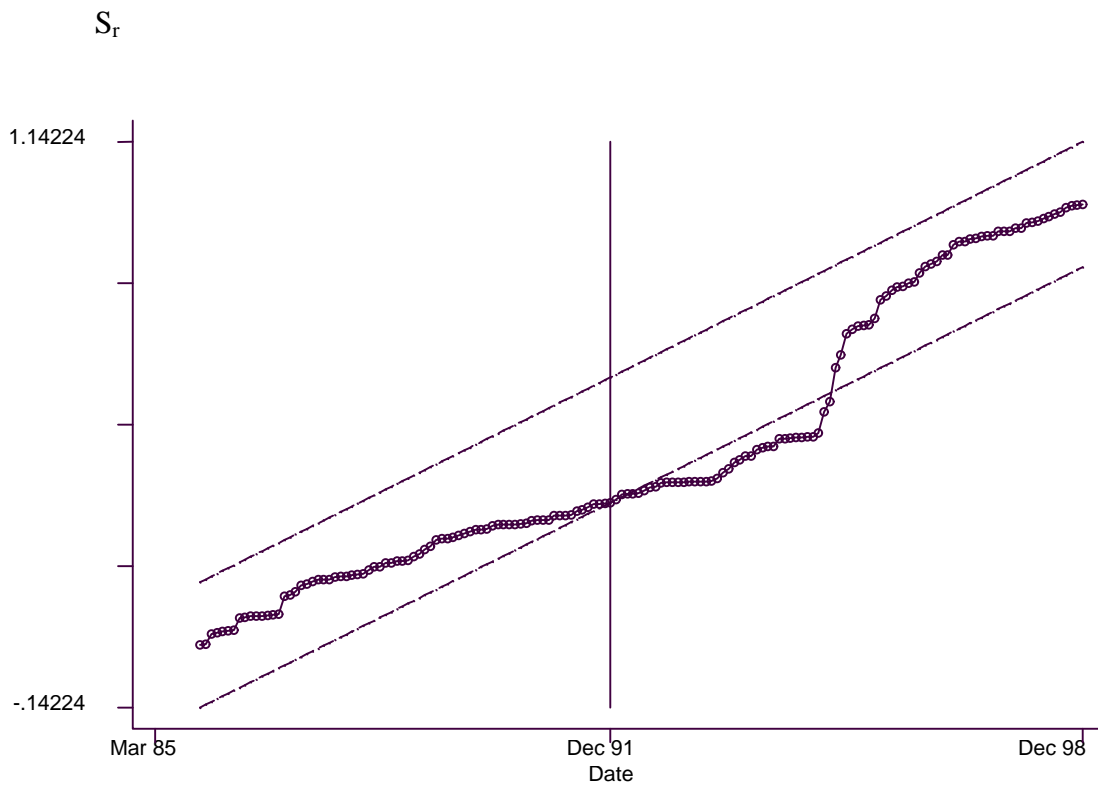
**Dependent Variable: Monthly Number of RJVs Filed, 1985-1998**

<b>Independent Variable</b>	<b>Parameter Estimate</b>
Intercept	-9.088* (3.065)
<i>TECHCOMP</i>	-0.040* (0.007)
<i>DEVINT</i>	0.119** (0.050)
<i>BCYC</i>	0.031** (0.013)
<i>M&amp;A</i>	-0.407* (0.123)
<i>DGOV1</i>	-1.721* (0.574)
<i>DGOV2</i>	-0.402* (0.107)
Log Likelihood	-387.22
$\chi^2(1) (\alpha= 0)$	82.31*
n	166

**Notes:** Heteroskedastic-consistent standard errors are reported in parentheses.

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

**Figure 2**  
**Plot of Kolmogorov-Smirnov Test Statistic ( $S_r$ ) from Brown-Durbin-Evans**  
**CUSUMSQ Test for Structural Change**



**Notes:** ----- lines indicate the 95% confidence limits for the Kolmogorov-Smirnov statistic derived from the Brown-Durbin Evans CUSUMSQ test for structural change

**Table 4**  
**Negative Binomial Parameter Estimates of the Propensity to File RJVs,**  
**With Controls for ATP-Induced Structural Change**

**Dependent Variable: Monthly Number of RJVs Filed, 1985-1998**

Independent Variable	Parameter Estimate		
	(1)	(2)	(3)
Intercept	-2.364 (6.418)	-8.493 (7.800)	9.038 (13.871)
<i>DATP</i>	21.100 (15.335)		
<i>TECHCOMP</i>	-0.043* (0.007)	-0.070* (0.023)	-0.769* (0.255)
<i>TECHCOMP*DATP</i>	-0.764* (0.243)		
<i>DEVINT</i>	0.075 (0.063)	0.112 (0.066)	0.019 (0.231)
<i>DEVINT*DATP</i>	-0.263 (0.215)		
<i>BCYC</i>	-0.010 (0.038)	0.053 (0.048)	-0.065 (0.055)
<i>M&amp;A</i>	-0.213 (0.288)	-1.501** (0.590)	0.204 (0.407)
<i>DGOV1</i>	-2.185* (0.588)		-2.188* (0.584)
<i>DGOV2</i>	-0.979* (0.207)		-0.984* (0.211)
Log Likelihood	-381.95	-157.48	-220.59
$\chi^2(1) (\alpha=0)$	49.29*	1.28	56.52*
n	166	81	85

**Notes:** Heteroskedastic-consistent standard errors are reported in parentheses.

\* significant at the .01 level

\*\* significant at the .05 level

*DATP* =1 from March 1991 through end of 1998; 0 otherwise. This breakpoint was identified based on the Brown-Durbin-Evans CUSUMSQ test for structural stability.