An econometric analysis of trends in research joint venture activity

By: Albert N. Link, David Paton, and Donald S. Siegel

Link, A.N., D. Paton, & D.S. Siegel. "An Econometric Analysis of Trends in Research Joint Venture Activity," *Managerial and Decision Economics*, 2005, 26: 149-158. https://doi.org/10.1002/mde.1209

Abstract:

Edith Penrose noted that firms may need to rely on research joint ventures (RJVs) to acquire access to resources that can help them achieve and sustain a competitive advantage. We estimate an econometric model of the propensity of firms to disclose their intention to engage in RJVs, in order to explain the recent precipitous decline in RJVs filed with the US Department of Justice. We find that RJV activity is inversely related to the competitive position of US firms in global high-technology industries and that the establishment of the US 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 RJVs: a substantial improvement in US global performance in high-technology markets and a sharp decline in ATP funding.

Keywords: research joint ventures | RJVs | Advanced Technology Program (ATP) | research and development

Article:

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.'[1] 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.[2] 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 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.[3]

As shown in Figure 1, the number of firms filing RJVs with the US 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 US

---

[1] This purpose is stated as a preamble to the Act. For an historical perspective on the NCRA see Scott (1989) and Link et al. (2002).

[2] 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 et al. (1992) and Combs (1993).

[3] 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 et al. (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*.

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.

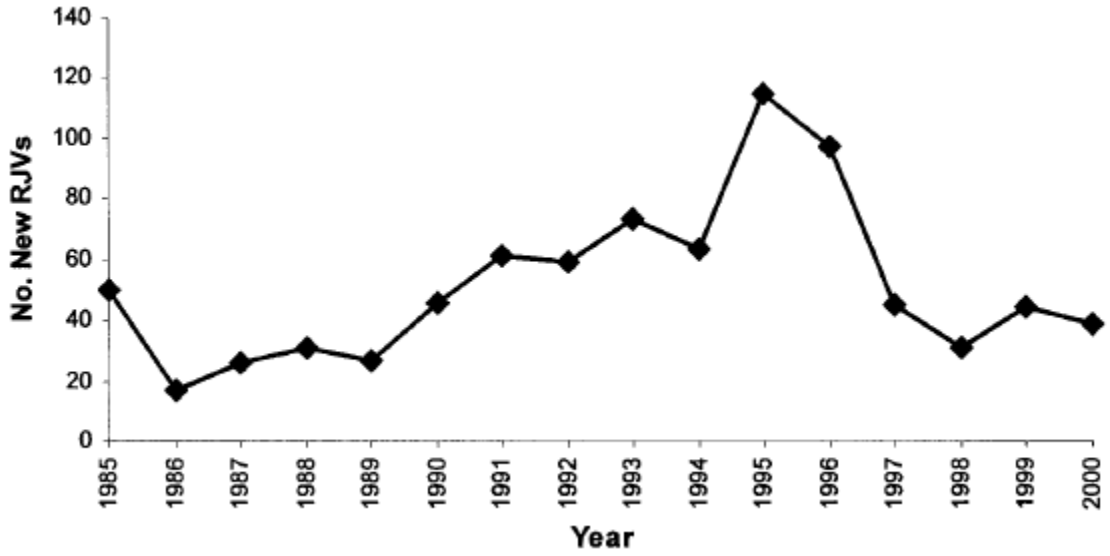

Figure 1. Annual counts of new research joint ventures, 1985–2000. Source: CORE database (National Science Board 2000). Notes: Data are available in the CORE database through 2000; however, our econometric analysis is from 1985–1998, due to a lack of data after 1998 on several independent variables.

One of the first scholars to point out that firms may need to rely on research joint ventures to acquire access to resources that can help them achieve and sustain a competitive advantage was Penrose (1959). Penrose asserted that in order to achieve a competitive advantage, a firm's resources must be rare, non-substitutable, and difficult for other firms to imitate. To maximize the return on these resources, firms may need to gain access to external complementary resources (e.g. technological resources) that can only be acquired through formal partnerships with another organization (Richardson, 1972). As this resource-based view of the firm has spread, a burgeoning theoretical and empirical literature of the antecedents and consequences of research partnerships has emerged from Penrose's seminal book (see Hagedoorn et al. (2000), Hall et al. (2001), and Siegel (2003)).

The purpose of this paper is to understand the underlying economic rationale for the decline in the incidence of US RJV filings. To accomplish this objective, we outline and estimate a time series econometric model of the propensity of firms to file their RJV intentions. 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. First, the econometric model is described. Next, the empirical results are presented. Finally, the concluding section of the paper discusses the implications of our findings.

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 threat. Such alliances could enable companies to reduce innovation costs and also accelerate the rate of product or process development.[4] Additionally, when US firms are experiencing such competitive pressure, they might assume that the federal government will be much less aggressive in pursing 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 US high-technology firms and their propensity to file RJVs with the US government.[5]

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 aspect of R&D.[6] Furthermore, the enhanced risk and uncertainty associated with basic research (relative to other types of 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 disclosing their RJV activities.[7]

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, and because of the strategic nature of these arrangements, to disclose them to gain antitrust protection. Alternatively, when economic conditions are favorable, they may use profits or retained earnings as a cushion to support

---

[4] See Hagedoorn et al. (2000) for a review of this theoretical literature.

[5] Of course, the law of comparative advantage suggests that not all industries will face the same competitive pressure from abroad at the same time. However, we hypothesize through this variable that competitive pressure per se will relax antitrust enforcement thus leading to fewer RJV disclosures.

[6] See Link and Bauer (1989) for a theoretical explanation. Briefly, Link and Bauer argue (p. 76) that firms engaging in cooperative research have their own incentives for directing their investments toward basic research. Since basic research has more public good characteristics than applied research or development, firms are not able to fully appropriate the returns to the resulting knowledge, as they would if the basic research were conducted privately. Hence, they may be more willing to share the costs of conducting basic research.

[7] Implicit in this hypothesis is the assumption that firms that engage in collaborative research also make that collaboration public through their filings. Hertzfeld et al. (forthcoming) provide evidence in support of this assumption. They find that while firms are involved in more collaborative ventures than they file with the US Department of Justice, the non-filed collaborations are generally very narrow in scope, short-term in length, and unrelated to long-run strategic research strategies. These 'informal' relationships come about, generally, to solve very specific technical problems related to production.

internal research projects. Thus, we anticipate observing an inverse relationship between proxies for the business cycle and RJV activity.[8]

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 an innovation that arises from the research project.[9] Relatedly, it is conceivable that companies engaging 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 filed RJVs and M&A activity.

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

$$RJV = F(TECHCOMP, DEVINT, BCYC, M\&A, \mathbf{Z}) \tag{1}$$

where *TECHCOMP* is a proxy for the competitive position of US 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 **Z** denotes a vector of additional control variables.

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

$$RJV_t = \beta_0 + \beta_1 TECHCOMP_t + \beta_2 DEVINT_t + \beta_3 BCYC_t + \beta_4 M\&A + \beta_5 DGOV1 + \beta_6 DGOV2 + \varepsilon_t \tag{2}$$

where ε_t is a disturbance term.

Definitions of the variables in Equation (2) are provided in Table 1, while summary statistics are presented in Table 2. 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 (*DG0V2*).

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 binomial (NB), or generalized Poisson, specification of Equation (1).[10] The basic Poisson model as applied to RJV filings is

---

[8] 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.

[9] See Link (1988) for preliminary evidence on this. Also, Kang and Johansson (2000) argue from a global perspective that M&As may take place to provide the initiating firm with needed intangible assets, including technology, which we argue could alternatively be obtained through collaboration.

[10] See Hausman et al. (1984).

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

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

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

where $\delta = 1/\alpha$ and $p = \left(1 + \alpha\left(\exp^{f(x)}\right)\right)^{-1}$. 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 χ^2 statistic (with one degree of freedom) for the test of the null hypothesis that α=0; that is, that the data are distributed as Poisson (conditional on **X**). Since we can reject this restriction in each case, we only report the NB estimates of variants of Equation (2).[11]

Table 1. Variable Definitions

Variable	Definitions	Data source
RJV	Monthly number of RJVs filed with the US Department of Justice, 1985–1998[a]	NSF CORE database (National Science Board 2000)
TECHCOMP[b]	US trade balance in advanced technology products, monthly, 1985–1998	US Department of Commerce, *US Trade with Advanced Technology* (see McGuckin et al., 1989)
DEVINT	Annual percentage of industry-funded R&D allocated to development, 1985–1998	National Science Board, *Science & Engineering Indicators 2000*, Tables A2-6 and A2-17 and unpublished data from NSF
BCYC	12 month weighted average of US industrial production index, (1992 = 100), seasonally adjusted, quarterly, 1985–1998	Board of Governors, *Federal Reserve Bulletin*, monthly
M&A	Annual number of US Mergers and acquisitions, 1985–1998	Thomson Financial Securities data, Mergers & Corporate Transactions Database
DGOV1	= 1 July 1995 to November 1995; 0 otherwise	Interviews with pre-merger group at Department of Justice
DGOV2	= 1 in December 1995 and January 1996; 0 otherwise	Interviews with pre-merger group at Department of Justice

[a] Data are available on RJVs in the CORE database on the day that the RJV was noticed in the *Federal Register*. These e 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

[11] Another issue raised by our approach is that we implicitly assume that these variables are stationary. It is not clear from the literature whether standard tests for stationarity apply with count data. This lack of clarity in the literature precludes a formal treatment of this issue here. However, standard stationarity tests (available from the authors upon request) suggest that the key variables in our model are indeed stationary and to the extent that these tests are applicable to count data, this provides support for our approach.

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*.

[b] Our prior was that only contemporaneous effects would affect the propensity of firms to disclose their RJV intensions since this variable proxies short-run investment decisions and short-run antitrust attitudes. Econometrically, lagged effects on this variable were statistically insignificant.

Table 2. Summary Statistics

Variable	Mean	SD	Min	Max
RJV	4.319	4.180	0	24
TECHCOMP	8.221	9.986	1.132	32.498
DEVINT	70.321	1.416	67.905	72.419
BCYC	105.098	13.274	87.627	134.108
M&A	2.040	1.315	0.785	6.092

Notes: All statistics are based on the sample period from March 1985 to December 1998=166 observations.

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

Dependent variable: monthly number of RJVs filed, 1985–1998	
Independent variable	**Parameter estimate**
Intercept	–9.088* (3.065)
TECHCOMP	–0.040* (0.007)
DEVINT	0.119** (0.050)
BCYC	0.031** (0.013)
M&A	–0.407* (0.123)
DGOV1	–1.721* (0.574)
DGOV2	–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 0.01 level;
**significant at the 0.05 level.

EMPIRICAL RESULTS

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.[12] We also report the χ^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 US firms in global high-technology industries and the formation and disclosure 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 formal 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.

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 that the new administration would engage in stricter enforcement of antitrust policy. This perception might induce 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 US 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 (Ghsyels et al., 1997) are typically based on the

[12] The results from alternative lag structures are available from the authors upon request.

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.[13]

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:

$$S_r = \left[\sum_{k+1}^{r} w_i^2 \Big/ \sum_{k+1}^{N} w_i^2\right], r = k, \ldots, N \tag{5}$$

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 Sr 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 C0, we have identified a point where structural change has occurred.[14]

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 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

[13] 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 et al., 1998).

[14] An alternative summary test of structural stability, which is also based on the cumulative sum of residuals, was suggested by Hansen (1992).

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 through collaboration. 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*.

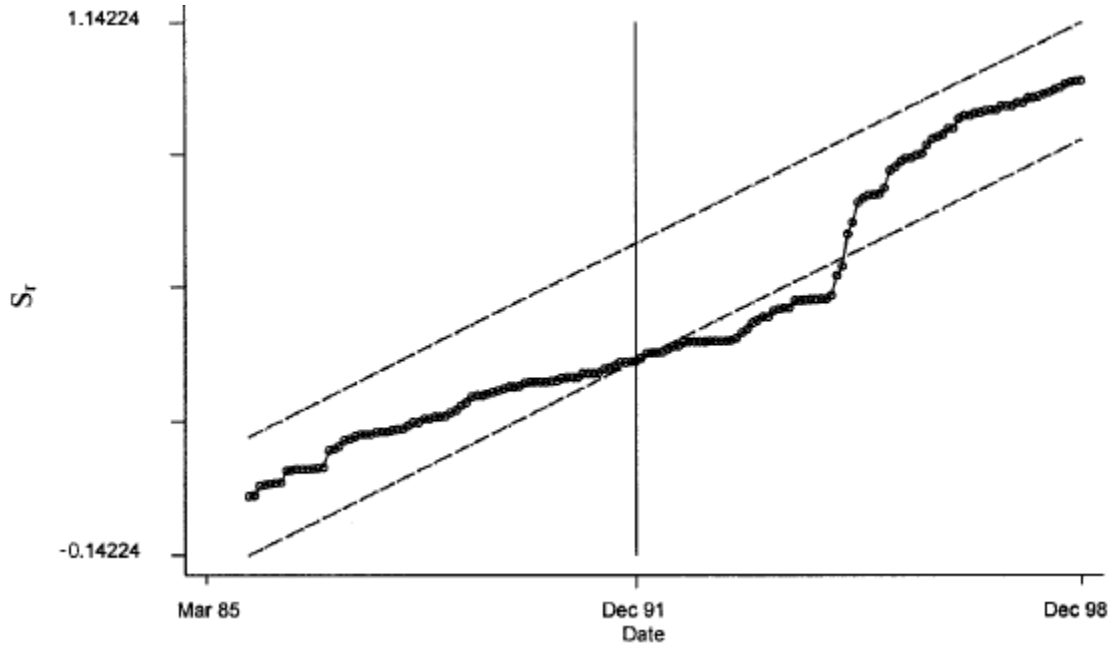

Figure 2. Plot of Kolmogorov–Smirnov test statistic (S_r) from Brown–Durbin–Evans CUSUMSQ test for structural change. Notes: - - - - lines indicate the 95% confidence limits for the Kolmogorov–Smirnov statistic derived from the Brown–Durbin–Evans CUSUMSQ test for structural change.

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.[15] Note, however, that splitting the sample appears to weaken our earlier findings regarding the responsiveness of RJVs to the intensity of R&D devoted to development and the

[15] The difference in the pre- and post-ATP coefficients on *TECHCOMP* is significant at the 0.05 level.

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

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			
	Parameter estimate		
Independent variable	**(1)**	**(2)**	**(3)**
Intercept	–2.364	–8.493	9.038
	(6.418)	(7.800)	(13.871)
DATP	21.100		
	(15.335)		
TECHCOMP	–0.043*	–0.070*	–0.769*
	(0.007)	(0.023)	(0.255)
*TECHCOMP*DATP*	–0.764*		
	(0.243)		
DEVINT	0.075	0.112	0.019
	(0.063)	(0.066)	(0.231)
*DEVINT*DATP*	–0.263		
	(0.215)		
BCYC	–0.010	0.053	–0.065
	(0.038)	(0.048)	(0.055)
M&A	–0.213	–1.501**	0.204
	(0.288)	(0.590)	(0.407)
DGOV1	–2.185*		–2.188*
	(0.588)		(0.695)
GDOV2	–0.979*		–0.984*
	(0.207)		(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. *DATP* = l from March 1991 through end of 1998; 0 otherwise. This breakpoint was identified based on The Brown–Durbin–Evans CUSUMSQ test for structural stability.
*Significant at the 0.01 level.
**Significant at the 0.05 level.

INTERPRETATION OF RESULTS AND CONCLUSIONS

Our empirical evidence sheds some light on possible causes of the precipitous decline in RJV filings with the US Department of Justice 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 (e.g. safe harbor from antitrust concerns) 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 US 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 US 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 US firms in high-technology industries increased from 29.2% in 1994 to 37.5% in 1998. The US Commerce Department reports that the budget for the ATP declined from a peak of $512 million in 1995 to $212 million in 1998.

There are several interpretations of our finding that a structural change in the regression equation occurs soon after the establishment of the ATP. Each of these interpretations is 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 along this dimension. 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 in support of *additionality*, or the notion that firms that receive ATP support for collaborative research are more likely to engage on their own in additional collaborative activities (Feldman and Kelley, 2003; Link, 1996).[16]

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 additional 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. Finally, it would be useful to extend Penrose's ideas on the outcomes of RJVs to public-private partnerships, by examining whether RJVs that receive financial support from the government are more likely to help firms achieve and sustain a competitive advantage than comparable privately-funded RJVs. The intersection between Penrose's resource-based view of the firm and public policy initiatives is a fruitful area of research.

Acknowledgements

This research was funded by the National Science Foundation, Science Resources Studies Division. We gratefully acknowledge comments from Susan Cozzens, John Jankowski, Adam Jaffe, Geoff Shephard, and participants at the November 2000 CNRS/CREST/CEPR/NBER International Conference on Technology Policy and Innovation in Paris, the February 2001 Network of Industrial Economists Conference at the University of London-Royal Holloway, the June 2001 DRUID Nelson and Winter Conference, and the October 2001 National Science

[16] This spillover effect is also discussed in Audretsch and Feldman (1996) and Audretsch and Stephan (1996).

Foundation Workshop on Intellectual Property Protection Mechanisms and Research Partnerships.

REFERENCES

Anders G, Siegel D, Yacoub M. 1998. Does Indian casino gambling reduce state revenues? Evidence from Arizona. Contemporary Economic Policy 16: 347–355.

Audretsch DB, Feldman MP. 1996. R&D spillovers and the geography of innovation and production. American Economic Review 86: 630–640.

Audretsch DB, Stephan PE. 1996. Company-scientist locational links: the case of biotechnology. American Economic Review 86: 64l–652.

Bai J, Peron P. 1998. Estimating and testing linear models with multiple structural changes. Econometrica 66: 47–78.

Brown RL, Durbin J, Evans JM. 1975. Techniques for testing the constancy of regression relationships over time. Journal of the Royal Statistical Society (Series B) 37: 149–163.

Combs K. 1993. The role of information sharing in cooperative research and development. International Journal of Industrial Organization 11: 535–551.

Feldman M, Kelley M. 2003. Leveraging research and development: assessing the impact of the US advanced technology program. Small Business Economics 20: 153–165.

Ghosal V, Gallo J. 2001. The cyclical behavior of the department of justice's antitrust enforcement activity. International Journal of Industrial Organization 19: 27–54.

Ghysels E, Guay A, Halk A. 1997. Predictive tests for structural change with unknown breakpoint. Journal of Econometrics 82: 209–233.

Hagedoorn J, Link AN, Vonortas NS. 2000. Research partnerships. Research Policy 29: 567–586.

Hall B, Link A, Scott J. 2001. Barriers inhibiting industry from partnering with universities: evidence from the advanced technology program. Journal of Technology Transfer 26: 87–98.

Hansen B. 1992. Testing for parameter instability in linear models. Journal of Policy Modeling 14: 517–533.

Hausman J, Hall BH, Griliches Z. 1984. Econometric models for count data with an application to the patents-R&D relationship. Econometrica 52: 909–938.

Heller RH, Khan MS. 1979. The demand for money and the term structure of interest rates. Journal of Political Economy 87: 109–129.

Hertzfeld HR, Link AN, Vonortas NS. Intellectual property protection mechanisms and research partnerships. Research Policy, (forthcoming).

Kamien M, Mueller E, Zang I. 1992. Research joint ventures and R&D cartels. American Economic Review 82: 1293–1306.

Kang N, Johansson S. 2000. Cross-border mergers and acquisitions: their role in industrial globalization. OECD Working Paper STI/86036.

Katz M. 1986. An analysis of cooperative R&D. Rand Journal of Economics Winter: 527–543.

Link AN. 1980. Firm size and efficient entrepreneurial activity: a reformulation of the Schumpeter hypothesis. Journal of Political Economy 88: 771–782.

Link AN. 1988. Acquisitions as sources of technological innovation. Mergers and Acquisitions November/December: 36–39.

Link AN. 1996. Evaluating Public Sector Research and Development. Praeger Publishers: New York.

Link AN, Bauer LL. 1989. Cooperative Research in US Manufacturing. Lexington Books: Lexington, MA.

Link AN, Paton D, Siegel DS. 2002. An analysis of policy initiatives to promote strategic research partnerships. Research Policy 31: 1459–1466.

McConnel MM, Perez-Quiros G. 2000. Output fluctuations in the United States: what has changed since the early 1980s? American Economic Review 90: 1464–1476.

McGuckin RH, Abbott III TA, Herrick PE, Norfolk L. 1989. Measuring the trade balance in advanced technology products. Center for Economic Studies Discussion Paper 89-1, US Census Bureau.

National Science Board. 2000. Science and Engineering Indicators. National Science Foundation: Arlington, VA.

Patterson KD. 2000. An Introduction to Applied Econometrics: A Time Series Approach. Macmillan: London.

Penrose ET. 1959. The Theory of the Growth of the Firm. Oxford University Press: Oxford.

Philips P, Perron P. 1988. Testing for a unit root in time series regression. Biometrica 75: 335–346.

Richardson GB. 1972. The organization of industry. Economic Journal 82: 883–896.

Scott JT. 1989. Historical and economic perspectives of the national cooperative research act. In Cooperative Research and Development: The Industry–University–Government Relationship, Link A, Tassey G (eds). Kluwer Academic Publishers: Boston; 65–84.

Siegel DS. 2003. Data requirements for assessing the impact of strategic research partnerships on economic performance: analysis and recommendations. Technology Analysis and Strategic Management 15: 207–225.

Winkelmann R, Zimmerman K. 1995. Recent developments in count data modeling: theory and an application. Journal of Economic Surveys 9: 1–24.