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How Do Research Joint Ventures Exploit Government R&D Programs?: Evidence from the National Cooperative Research Act, the Advanced Technology Program, and the Department of Defense

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Abstract –

One view of government programs to support R&D is that they should encourage positive informational externalities or "knowledge spillovers." It is not obvious, however, that private parties always exploit such programs in ways conducive to spillovers. Specifically, firms might only participate in R&D joint ventures if they would not be required to contribute important knowledge inputs or if they could get away with contributing knowledge inputs that are less susceptible to spillover. Indeed, the purpose of contributing knowledge inputs often appears to involve less in the way of inducing knowledge transfers and more in the way of providing joint venture partners rights-of-way to conduct collaborative R&D. Another view is that government programs should enable firms to avoid duplicative costs. There is evidence that cost-sharing is, indeed, the principal motivation for organizing certain ventures.

Keywords: research joint ventures, uncertain property rights, Background Intellectual Property, Foreground Intellectual Property, nondisclosure agreements.

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0. Introduction

Economic distress often concentrates attention in policy circles on innovation and the competitiveness of American industry. In the run up to World War II, for example, the country was mired in the second dip of double-dip depression, and concerns became focused on the encroachments of German cartels in munitions-related technologies and industries (Borkin 1943, 1978). In the late 1970's, concern started to concentrate on the perceived loss of leadership to Japanese firms in the development and production of semiconductors and other computer hardware (Corey, 1997, p. 111). The experience of the late 1980's and early 1990's brought much of the same, with proponents of activist policy raising concerns over Japanese investments in superconductivity and HDTV (Bingham and Papadakis 1998, Mowery and Rosenberg 1989).

Each of these episodes inspired policy responses. The experience in 1937 inspired an anti-cartel enforcement campaign. The experience of the late 1970's inspired debate over how disjointed American R&D programs might be reordered (if at all) to meet Japanese industrial policy. Out of the debate emerged an alphabet soup of (still disjointed) legislation and programs including the National Cooperative Research Act of 1984 (NCRA). Concern then became concentrated on the perception that foreign firms had proven to be more adept than American firms at commercializing technologies, including technologies invented in the United States (Schacht 2006, 1995; Dertouzos, Lester and Solow 1990, pp. 66-80; Mowery and Rosenberg 1989). Hence the motivation for a new sequence of programs including the Advanced Technology Program (ATP) and SEMATECH. The recession of the early 1990's prompted expansion and some reordering of the ATP as well as extension of the NCRA to the National Cooperative Research and Production Act of 1993.

Many of these initiatives contemplated government subsidies, and most contemplated the participation of private parties (firms and university researchers). Many of those, in turn, explicitly contemplated collaborative R&D by which private parties would organize research joint ventures. After all these years, however, it remains non-obvious how one might evaluate any of these initiatives. (On this count see, among others, Jaffe 2008 and Klette et al. 2000.) Do such initiatives yield R&D that would not otherwise have obtained? Might such initiatives even yield over-investment in R&D? Or, as the proponents of the NCRA argued, do parties engage in "duplicative" R&D and thus have the appearance of over-investing? Alternatively, absent subsidies, do private parties under-invest? Do policy initiatives yield positive externalities – "knowledge spillovers" – that might justify government subsidies, or do spillovers inspire private R&D thus mitigating the need for subsidies? Most importantly, how might one assemble the counterfactual by which one could compare how investment resources would have been deployed absent government inducements?

There is abundant research demonstrating that spillovers and attending appropriability hazards are important phenomena, but securing crisp answers to any of the other questions remains a formidable challenge. Nelson and Langlois (1983) could observe that "[A]nalyzing the effects of government policy on industrial innovation must still be seen as largely an empirical problem—which policies have worked, which have not, and why." Yet, a generation later Jaffe (2008) could observe, "There has been much work on these topics in the last three decades, but there remain difficult problems of finding proxies for subtle concepts, endogeneity, distinguishing private and social returns, untangling cumulative effects, [and] measuring the impact of government programs in a true 'but for' sense…"

This paper takes up one aspect of distinguishing private and social returns: how have certain government programs anticipated and accommodated – or not accommodated – knowledge spillovers in R&D joint ventures? It has been long understood that investments in R&D yield knowledge spillovers (positive informational externalities). It is further understood that such spillovers generate social returns that exceed the private returns from those same investments. (See, for example, Griliches 1979,1992, p. 43; Jaffe 1998; and Campbell et al. 2009.) Private parties, in turn, would be expected to under-invest in R&D. Then, as some observers note, some scope may obtain for directing public subsidies to otherwise private R&D initiatives (e.g., Campbell et al. 2009, Siegel et al. 2003). But which private initiatives should receive support?

In a paper inspired by the experience of the Advanced Technology Program, Jaffe (1998) illuminates some of the hazards involved in selecting private initiatives for public funding. Choosing initiatives that have good commercial prospects might not make sense, because private parties would likely recognize those good prospects and fund the initiatives themselves. Public funding will have merely displaced private funding. Instead, funding should be directed toward projects that have lesser commercial prospects. But not all such projects. Projects with low social returns should be passed over. Good candidates for funding would be those projects for which much of the social return is derived from spillovers. Such projects would include those that feature large knowledge spillovers but yield (not too surprisingly) low private returns.

All well and good, but the non-trivial problem of identifying projects that yield substantial spillovers remains. It is well appreciated that spillovers are difficult to observe (much less forecast). Indeed, paraphrasing Paul Krugman (1991), Jaffe notes that spillovers "leave no paper trail" (Jaffe 1998, p. 17). Accordingly, as Jaffe observes, research on spillovers has had to focus on inferring their existence from other indications such as correlations between the R&D inputs of certain entities and the R&D outputs of other entities. Even so, research informed by an economics-of-organization perspective indicates that spillovers do leave various kinds of paper trails. Among other things, they leave a trail of contracts. Specifically, knowledge spillovers (and appropriability hazards more generally) are understood to influence the design of contracts and other mechanisms governing collaborative R&D. (See, for example, Oxley 1997, Contractor and Ra 2002, Sampson 2004, Majewski and Williamson 2004).

The research presented here works out of a unique dataset of 171 research joint venture contracts. These contracts were extracted from filings to the Department of Justice made under the terms of the National Cooperative Research Act of 1984 and its successor act, the National Cooperative Research & Production Act of 1993 (hereafter collectively referred to as the "NCRA" or "the Act"). The contracts are interesting, because certain objectively identifiable dimensions of them are relevant to the analysis of spillovers. It is broadly understood, for example, that "tacit knowledge" can only be transferred by means of personnel transfers (Anand and Galetovic 2000, Teece 1986). The various R&D "collaboration agreements" and "licensing agreements" between the genomics firm Human Genome Sciences (HGS) and the pharmaceuticals firm SmithKline Beecham (SKB) are illuminating on this point.[1] The contracts featured explicit provisions according to which SmithKline Beecham reserved the right to detail a few of its personnel to HGS facilities to work with HGS personnel. By working alongside HGS personnel, SKB personnel could absorb "know-how" that would allow them to apply the HGS technology to the development of pharmaceuticals. In contrast, many other contracts in the dataset do not provide such visitation rights. Indeed, R&D partners may restrict the physical proximity of researchers in order to frustrate unintended knowledge spillovers.

This particular dataset of contracts is interesting, because it is just that: a dataset of *actual* contracts. Most research on R&D joint ventures has to work out of datasets that describe selected features of joint ventures. This dataset is also interesting, because the contracts allow one to identify distinctions between government-subsidized joint ventures and joint ventures that received no such support. Specifically, 55 of the 171 contracts involved government subsidies with 20 contracts involving funding from the ATP, another 23 involving funding from the Department of Defense, and yet another 20 involved funding from other government entities.

Government-subsidized ventures distinguish themselves by their restrictive orientation to the input of knowledge assets to collaborative R&D. Two distinctions are illuminated here: government-subsidized ventures have tended to involve either (1) collaboration that did not heavily depend on the sharing of knowledge inputs, or (2) the input of knowledge assets that are less susceptible to unintended spillover. First consider knowledge sharing. There is a body of ATP-sponsored research that suggests that ATP-sponsored ventures have tended to promote the sharing of the knowledge *outputs* of collaborative R&D.[2] Other ATP-sponsored research suggests that research joint ventures have tended to be more successful (by certain metrics) when they have been designed to encourage the sharing of knowledge *inputs* (Dyer et al. 2007), the stuff that R&D partners formally recognize in contracts as "Background Intellectual Property." Yet, the ATP-sponsored ventures examined in this paper do *not* appear to have been designed to transfer knowledge inputs. Rather, ATP-sponsored ventures appear to have been designed to contain spillovers of Background Intellectual Property in that few made allowances for personnel transfers of the sort formalized in the HGS/SKB contracts. In contrast, more than a third of the non-subsidized joint ventures involved some type of visitation rights.

Now consider the unintended spillover of Background Intellectual Property. Parties to government-subsidized joint ventures appear to have organized collaboration around Background Intellectual Properties that were less susceptible to unintended spillover. The evidence includes the fact that these same ventures tended to apply to Background Intellectual Properties nondisclosure agreements (NDA's) of long duration. NDA's, it turns out, are both common and curious features of contracts governing collaborative R&D. They are common, because practitioners appreciate that they can help firms contain unintended knowledge

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[1] Contracts are included as exhibits in the HGS quarterly report (SEC Form 10-Q) dated August 20, 1996. The two parties made an NCRA filing in 1993.

[2] See, for example, Campbell et al. 2009, p. 312 and especially Feldman and Kelley 2003, p. 158: "[F]irms receiving funding from ATP were more likely to have extensive linkages to other businesses and to profess a greater willingness to share information about their research findings with other firms. This indicates that the knowledge and technologies developed by the aware-wining projects were more likely to be diffused quickly through the extensive linkages of the firms and their greater willingness to make their research results available to other firms and their greater tolerance of knowledge leakages."

spillovers (Fitzpatrick and Burke 2003). NDA's are curious, because they vary widely in duration (Majewski and Williamson 2004). The puzzle is that if NDA's contain spillovers, then one might expect them to run a very long term or even to run indefinitely, which they sometimes do. But in most cases they run a few years or less. What explains the variation?

The resolution of the puzzle proposed here involves a simple tradeoff: intellectual properties vary in the degree to which NDA's can contain spillovers. Where they are effective, it can make sense to assign NDA's of long duration. Yet, where they are not effective, NDA's can invite mischief. They can allow firms to game legalistic processes by asserting false claims of improper disclosure on the part of R&D partners. Anticipating this, R&D partners will assign NDA's of short duration or dispense with them entirely.

The analysis presented here amounts to comparing and contrasting the structure of R&D joint ventures to the typical "baseline" venture represented by the NCRA data. One might wonder about how the typical venture filed with the NCRA deviates (if at all) from the typical venture represented by the universe of research joint ventures. I have no observations about how the decision to file or not file information with the NCRA might induce biases, and I leave the matter of substantiating differences between NCRA-filed ventures and all other ventures to further research.

The remainder of the paper proceeds in five parts. In the next section I both describe the NCRA and explain the motivation for its enactment. I also motivate the proposition that there is discriminating alignment between the duration NDA's and the degree to which intellectual properties are susceptible to spillover. In the section after that I relate the experience of the ATP. I then describe the contract data. I present results in the fourth part. Some results proceed from probit analysis of selected dimensions of contract, and others proceed from duration analysis of the NDA's embedded in research joint venture contracts. The last part concludes.

1. The National Cooperative Research Act and Non-disclosure Agreements

In 1983 Japan's new prime minister Yasuhiro Nakasone could declare that Japan had "caught up" with the West and that the country should anticipate the harder task of assuming and maintaining leadership in the development and commercialization of new technologies (Nakasone 1983, p. 15). Nakasone went on to suggest that the private sector should assume this harder task without expecting the traditional support (or interference) of government (Nakasone 1983, p. 17). Even so, the Japanese government had already launched in 1980 and 1981 publicly-funded initiatives, the SuperSpeed and Fifth Generation Computer projects, aimed at securing for Japanese firms the lead in the development and commercialization of computer hardware.

Ironically, while Nakasone and his political allies were contemplating a smaller role for their government in channeling the nation's investment resources, some observers in foreign capitals exploited the announcements of the Japanese initiatives by escalating demands for their own governments to increase their roles in channeling investment. Some observers pressed their governments to implement "industrial policies" responsive to, if not explicitly modeled on, Japanese industrial policy. In the United States, for example, interested parties and their representatives in Congress assembled and pressed a broad menu of legislative initiatives aimed at restoring and preserving such things as the country's perceived lead in semiconductors and high-speed computing.[3] While most proposed legislation ultimately fell to the wayside, one of the various iterations of the National Cooperative Research Act eventually emerged from the brew of legislative initiatives.

The NCRA constituted but one of a handful of initiatives that the federal government rolled out in the 1980's to promote the competitiveness of American industry.[4] Proponents of the Act and of other initiatives argued that American firms should be permitted to collaborate on R&D in ways similar to those of their Japanese and European competitors. Collaboration, it was argued, would allow firms to share costs (and thus avoid duplicative R&D efforts) and to share knowledge.[5]

The NCRA contemplated research joint ventures (RJV's) that would be "horizontal" in that they would join actual or potential competitors. Allowing competitors to collaborate – and to do it in contractually formalized joint ventures! – would pose obvious antitrust concerns, but the Act qualified the approach by which the antitrust authorities would evaluate RJV's. The law had been situated such that merely forming an RJV would not trigger automatic scrutiny by the antitrust authorities, and the Act made plain that RJV's would continue to be relieved of automatic scrutiny. Nonetheless, the NCRA held out to any one candidate RJV some prospect of insulating it from one potential hazard if it were to proactively invite scrutiny. Specifically, Section 4 of the Clayton Act provides "injured" parties triple damages in private antitrust litigation. If the RJV were to invite scrutiny by proactively identifying itself and filing a report

[3] For example, in a hearing before the Joint Economic Committee of the 98th Congress (November 3, 1983), Ed Zschau, representative of California's 12th congressional district (the San Francisco peninsula, near 'Silicone Valley') testified that "Over the next decade, America's dominance in the computer industry will be challenged from abroad. The challenge will come from Japan. In 1981, after three years of extensive planning, the Japanese government announced a <u>national</u> <u>project</u> designed to make Japan number one in the computer industry by the late 1990s. It's a project to develop a 5th Generation computer—a machine so advanced in hardware and software that it will be able to 'reason with knowledge' like a human being…"

[4] In 1988 the government launched the SEMATECH consortium and situated the Advanced Technology Program in the National Institute for Standards and Technology. Flamm and Nagaoka (2007) further note that "The Stevenson-Wydler Technology Innovation Act of 1980 encouraged industry and government researchers to work together in Cooperative Research and Development Agreements (CRADAs). The Bayh-Dole University and Small Business Patent Act of 1980 was designed to encourage university researchers to transfer their technology to commercial companies."

[5] See, for example, the Senate Report on The National Cooperation Research Act of 1984, S. REP. NO. 98-427, reprinted in 1984 U.S.C.C.A.N. 3105, 3106. Cost-sharing and the kinds of knowledge-sharing that proponents had in mind anticipated collaborations that were horizontal in that they would join firms that were potential or even actual competitors. Evidence suggests that cost-sharing has, indeed, been an important dimension of some research collaborations organized under the terms of the NCRA, and there is evidence that knowledge-sharing has been important in yet other research joint ventures (Röller, Tomback and Siebert 2007, Majewski and Williamson 2004). The evidence suggests, however, that knowledge-sharing prevails in ventures that are more vertical in that they join parties that are situated to contribute complementary know-how and capabilities (Majewski and Williamson 2004). It turns out that not even Japanese research consortia conformed to the purportedly 'Japanese style' of collaboration in that they too tended to assume vertical, rather than horizontal, structures (Sakakibara 2003).

of its planned activities, then the Department of Justice might limit damages that could obtain in any subsequent litigation to actual damages.

Figure 1 features the distribution by year of NCRA filings from the inception of the NCRA through August 2009. In all, 1,343 filings have been made. Many of these filings do not pertain to collaborative R&D. The implementation in 1993 of the National Cooperative Research & Production Act encouraged some parties to report "production joint ventures." These ventures may have anticipated knowledge spillovers but did not necessarily contemplate important R&D. In 2004 the Act was further extended to "Standards Development Organizations" (SDOs). Two types of entities have appealed to SDO status: familiar entities like the IEEE that coordinate the inclusion of *existing* intellectual properties in technological standards, and certification authorities that promote professional standards in service industries. Since 2004, 260 SDOs have made NCRA filings. The 171 RJV's examined in this paper compose more than one-in-seven (15.8%) of the 1,083 non-SDO filings submitted since 1984.

Evidence from NCRA filings submitted since 1984 suggests that RJV's have promoted both cost sharing and knowledge sharing although not necessarily in ways anticipated by the proponents of the Act (Röller, Siebert and Tomback 2007; Majewski and Williamson 2004). Even so, this paper takes up a dimension of collaboration without which *no* cost-sharing or knowledge-sharing of any kind would obtain: the problem of securing rights-of-way to conduct R&D – or what Grindley and Teece (1997) would recognize as the "freedom to operate" – within the context of a collaborative venture. At first sight, the problem involves nothing more than resolving "hold-out"[6]: parties to a candidate collaborative venture may maintain property rights, including intellectual property rights, that would allow them to block joint R&D or to block the subsequent commercialization of technologies that might proceed from joint R&D. These rights might not even embody interesting knowledge, but parties might use them strategically in order to extract rents. With each rights-holder in a sequence of rights-holders holding out for a better deal, collaboration may be delayed or even frustrated. In an environment in which property rights are well defined, the solution is simple: before undertaking any joint R&D, the parties commit to a grand cross-licensing agreement by which each party implicitly grants to all other members rights-of-way to exploit within the context of the collaboration whatever intellectual properties upon which joint R&D may potentially make contact.

Resolving hold-out is an important problem, and in environments involving well defined property rights, hold-out may constitute the only important hazard that contracting parties must anticipate. In contrast, environments in which property rights are uncertain support a richer set of strategic behaviors and attending hazards. The problem derives from the fundamental fact that "property rights" imply legal process – formal process to which parties may appeal to sort out property rights violations. Characterizing violations depends on delineating property, yet that alone may constitute a nontrivial problem. A line in the sand might go far toward delineating the bounds of beachfront properties, and delineating properties will go some way toward allowing parties to demonstrate violations to third parties (e.g., the court or an arbitrator), but intellectual property rights may be uncertain in that neither contracting parties nor enforcement authorities may be able to distinguish fine lines between intellectual properties. That leaves open questions about whether one party would be able to detect violations to say

[6] Again, see Grindley and Teece (1997). See also Merges (1996).

nothing of proving violations to enforcement authorities. Moreover, practical difficulties encountered in delineating properties may frustrate efforts to characterize what might constitute violations in the first place. And it gets worse. Practical difficulties may enable the owners of intellectual properties to falsely assert misappropriations of intellectual property on the part of others and to game legalistic processes. Specifically, asserting misappropriations can enable the owners of intellectual properties to draw other parties into protracted legal processes, all in an effort to frustrate the efforts of these others to pursue R&D and to commercialize technologies (Lanjouw and Lerner 2001; Lanjouw and Schankerman 2001; Majewski and Williamson 2004). Claims of misappropriation might not have much merit, but demonstrating the merits (or demerits) of a claim to a third party (e.g., the court) can be costly (Williamson 1999).

The gaming of legalistic processes and problems of contract enforcement constitute opposite sides of the property rights coin. At first sight, much of the action in designing RJV contracts involves resolving generic hold-out problems: R&D partners will grant to each other rights-of-way to exploit intellectual properties that they each contribute to their ventures. That is they grant rights-of-way to what they formally recognize as “Background Intellectual Property”. R&D partners will also grant rights-of-way to exploit intellectual properties innovated within the context of collaboration (“Foreground Intellectual Property”). (That is, in fact, what R&D partners do in each of the 171 RJV’s examined here.) Yet, while granting rights-of-way may neutralize hold-out, rights-of-way may also facilitate unintended knowledge spillovers. Spillovers, in turn, may diminish the ability of parties to appropriate returns from investments in the R&D that yielded their intellectual properties. It is natural, then, that R&D partners might institute mechanisms that qualify rights-of-way.

R&D partners principally use NDA’s and licensing restrictions to qualify rights-of-way. Parties might, for example, reserve vetoes over the licensing of either Background or Foreground Intellectual Property to third parties. Restricting licensing may mitigate spillovers, but one tradeoff is that it may also frustrate the efforts of R&D partners to commercialize technologies. Similarly, parties might impose restrictions on the disclosure of intellectual property to third parties. Insofar as NDA’s are enforceable, then they may help parties contain spillovers, but, again, restricting disclosures may frustrate the efforts of parties to commercialize technologies.

While the enforceability of NDA’s speaks to the appropriability of intellectual property, remedies to the appropriability problem may allow parties to expropriate returns from their R&D partners. Appropriability depends on the ability of parties to detect violations and to demonstrate violations to third parties. In contrast, parties can exploit NDA’s by asserting violations on the part of R&D partners. Just as violations may be hard to detect, so too false claims may be difficult to distinguish from genuine claims. Making claims alone may be adequate for drawing R&D partners into protracted legalistic processes, all in an effort to expropriate rents. Anticipating the prospect of such gamesmanship, contracting parties might qualify the use of NDA’s. We thus end up with a compounded sequence of qualifications: Parties remedy appropriability problems by qualifying rights-of-way (through NDA’s), but the qualifications themselves introduce distortions that also invite qualifications.

Contracting parties qualify NDA’s by limiting their duration. Arora and Merges (2004) observe that “nondisclosure agreements between independent parties are difficult to enforce, owing in part to the complexity of defining the information to be kept secret and separating it from the pre-existing information of the parties" (p. 461) – which is part of the point. If NDA's were easy to enforce, there might be no reason to limit their duration. As it is, the duration of such restrictions varies widely. In some instances parties commit to NDA's that last a few years after the termination of collaboration. In other instances, NDA's may last indefinitely, and yet in some others parties may impose no restrictions. Ultimately, the duration of NDA's exhibits variation – variation that is amenable to survival analysis.

The hypothesis posed here is that the duration of NDA's reflects tradeoffs between appropriability and legalistic gamesmanship. Specifically, parties assign NDA's of longer duration intellectual properties that are more appropriable and NDA's of shorter duration intellectual properties that are more amenable to legalistic gamesmanship. The real interest in conducting survival analysis of NDA's, however, is less in testing the hypothesis but rather in using the hypothesis to reveal differences (if any) between the Background Intellectual Properties and Foreground Intellectual Properties parties contribute to government-subsidized ventures and to non-subsidized ventures. The exercise depends on differences in the appropriability of intellectual properties pertaining to "Chemicals" and "Electronics." Chemicals are widely understood to be more appropriable that electronics (e.g., example, Arora 1997), and the prediction that proceeds from the hypothesis would be that NDA's pertaining to chemicals would exceed those assigned to electronics – which they do by significant margins. Just as the Chemicals/Electronics dichotomy manifests itself in the duration of NDA's, so too does a dichotomy between government-subsidized ventures and non-subsidized ventures. Specifically NDA's assigned to Background Intellectual Property in government-subsidized ventures tend to be longer than NDA's assigned to Background Intellectual Property in non-subsidized ventures. An interpretation that parallels the Chemicals/Electronics dichotomy becomes plain: government-subsidized ventures tend to involve more appropriable Background Intellectual Property, not the kind of intellectual property that would be more susceptible to unintended spillover.

2. The Advanced Technology Program

The ATP was inspired by concerns that American firms had proven less capable than foreign (especially Japanese) competitors at commercializing technologies that those same American firms had first developed. (See, for example, Ruegg and Feller 2003, pp. 3-4.) It was established by Title V of the Omnibus Trade and Competitiveness Act of 1988 and started funding projects in 1990 with an annual appropriation of $10 million. By 1995 the ATP budget grew to $341 million with most funding directed to single-firm projects – a fact that had attracted criticism – but the ATP also had an explicit mandate to promote collaborative R&D (Idelson 1996, GAO 1996). The ATP was subject to some reform in 1997, and the America COMPETES Act of 2007 initiated the process of supplanting the ATP with the Technology Innovation Program, a program that is more heavily focused on collaborative ventures and "small and medium-sized firms" (Schacht 2009).

By the mid-1990's the ATP found itself waging a defensive political battle to justify its annual appropriations. A central problem was that it was not obvious what the ATP's mission was supposed to be or that it could execute it. Indeed, the principal concern that American firms were failing to commercial technologies did not suggest an obvious mission. Over time, however, the ATP and its proponents came to characterize its mission as supporting the development by American firms of intendedly "early stage, high-risk," "pre-competitive," "enabling technologies" that yield "broad-based economic benefits."[7] While it might not be obvious what such incantations mean, a reading of Jaffe (1998) suggests that one could recast the mission statement with the language of such theoretically-recognized concepts as "spillovers" and "appropriability": The ATP intendedly sponsored joint ventures pursuing the development of technologies that would be less amenable to appropriation (hence, "high-risk" and likely "pre-competitive") but would yield a high volume of knowledge spillovers (thus "enabling" the realization of "broad-based" benefits).

Opposition to the ATP started to mount by 1995. In that year, the Clinton administration proposed expanding ATP's annual appropriation to $750 million by 1997. The proposal invited a response: the Republican-controlled Committee on Science of the House of Representatives requested an evaluation of the program by the General Accounting Office (GAO). The GAO criticized ATP's self-evaluation methods, observing, among other things, that some of the ATP's methods amounted to little more than bean-counting (GAO 1995, pp. 6, 9). The ATP would, for example, report numbers of applications for ATP funding as well as numbers of ventures the ATP had selected for funding. Conceivably, one could fold these numbers into an analysis illuminating the volume of collaborative R&D that would not have been assembled but for ATP sponsorship, and the ATP did, in fact, present these numbers as evidence demonstrating the effectiveness of the program. Yet, absent defensible counterfactual benchmarks, such numbers reveal little.

The ATP made some effort to characterize counterfactuals. It surveyed parties that had applied for ATP sponsorship – both those to which the ATP had denied funding as well as those that had secured funding. Would the winners or losers have pursued collaborative R&D even absent ATP sponsorship? The GAO report of 1995 as well as a succeeding GAO report of 1996 used the answers to such questions to generate results of its own – results that observers characterized as "mixed." Specifically, both reports indicated that the ATP had financed projects that private parties would have financed absent the ATP subsidies as well as projects that parties would have abandoned (or did abandon) absent subsidies. Opponents of the ATP illuminated the former results and proponents illuminated the latter. Yet, before judging the ATP, one might prefer to fold the results into an analysis that demonstrates some awareness of the ATP's technology for screening applications. The GAO's criticisms, for example, amounted to finding that the screening technology would sometimes yield false positives: instances in which the ATP chose to fund ventures that likely yielded highly appropriable returns and would therefore have been able to secure private financing. ATP's self-reported successes, meanwhile, also ignore the prospect of false positives: the fact that some projects would not have secured private financing does not establish that they should have received sponsorship. Rather, even though such

[7] See, for example, the stream of testimony featured in the Hearing before the Subcommittee on Environment, Technology and Standards of the Committee on Science, House of Representatives, June 14, 2001 and Chapter 4 of the National Science Board report *Science &Engineering Indicators – 1998*, Arlington, VA: National Science Foundation, 1998 (NSB 98-l). See also Laidlaw (1998), Powell (1998), Chang, Shipp and Wang (2002), Feldman and Kelley (2003), Ruegg and Feller (2003), and Campbell et al. (2009).

ventures may not have yielded sizable private benefits, neither would they necessarily have yielded much in the way of knowledge spillovers.

That the ATP's screening technology would, like any screening technology, have yielded false positives and false negatives should be no surprise. Thus, merely counting perceived failures and successes again amounts to little more than bean-counting. As a matter of course, highly appropriable ventures will have sometimes secured funding, and less appropriable ventures that would otherwise have yielded a large volume of knowledge spillovers will sometimes have been passed over. A difficulty for the ATP, however, was that it had difficulty demonstrating that its screening technology was any good at avoiding errors. It was not well equipped to identify and measure spillovers. The best it could do was commission a draft report[8] that indicated that "'controlling for the effect of intra-industry information flows on appropriability, intraindustry R&D information flows complement firms' own R&D efforts, underscoring the social welfare benefits of such flows.' These findings are consistent with fundamental propositions leading to ATP's establishment" (Ruegg and Feller 2003, p. 228).

That was not the end it. The ATP may have had difficulty characterizing the spillovers induced by ATP-sponsored ventures. Outside reviewers, meanwhile, had less difficulty cataloguing instances in which the ATP ended up sponsoring ventures that should likely have been passed over. In a 2000 report, for example, the GAO evaluated three projects – not a large number – but determined that in each case entities competing with the joint venture partners had already been engaged in the commercialization of competing technologies for some time (GAO 2000, p. 4). GAO concluded that ATP had not been situated "to ensure that it [had been] consistently … funding existing or planned research that would [have not been] conducted in the same time period in the absence of ATP financial assistance." (GAO 2000, p. 5)

The GAO report opened with the observation that there had been "continuing debate over whether the private sector has sufficient incentives to undertake research on high-risk, high-payoff emerging and enabling technologies without government support, such as ATP" (GAO 2000, p. 3). This paper does not take up the debate but rather maintains the hypothesis that knowledge spillovers are important phenomena. The paper does take up questions that might yet inform debate: entities like the ATP may have difficulty identifying and measuring knowledge spillovers, but contracts provide clues about how joint venture partners have accommodated the spillover of knowledge inputs (Background Intellectual Properties) as well as the spillover of the knowledge outputs of collaborative R&D (Foreground Intellectual Property).

3. Data

The data derive from RJV contracts included in 171 NCRA filings.[9] Contracts are not work plans but rather are documents that set up rules and processes through which R&D partners

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[8] Wesley M. Cohen and John P. Walsh, "R&D Spillovers, Appropriability and R&D Intensity: A Survey Based Approach", Draft report, Advanced Technology Program (2000).

[9] About 1 in 7 NCRA filings include contracts relevant to collaborative R&D. I have no basis for suggesting that parties' decisions to include, rather than exclude, contracts from NCRA filings reflect selection biases. Additionally, I have no basis for suggesting that decisions to make NCRA filings selection reflect biases that would that skew the results of the survival analyses.

manage Background Intellectual Property and Foreground Intellectual Property. First and foremost, contracts provide rights-of-way: they universally feature implicit cross-licenses between R&D partners on Background Intellectual Property and Foreground Intellectual Property. There is no variation on this count. Instead, important variation in contracts shows up across three dimensions: the assignment of R&D efforts (who conducts R&D), the assignment of rights over the licensing of intellectual properties (who assumes rights to license Background or Foreground Intellectual Property to third parties), and the nature of personnel transfers (who maintains rights to visit the sites of important R&D). Variation, of course, also shows up in the duration of NDA's. All contracts feature NDA's.

One might expect that parties who conduct R&D and develop Foreground Intellectual Property would dictate the terms by which that Foreground Intellectual Property could be licensed. In some cases, however, R&D partners agree to assign to another party – possibly one of their own partners – the right to license Foreground Intellectual Property to non-member entities. R&D partners might do this, for example, to promote the adoption of the RJV's technologies by non-members. Meanwhile, it is well-understood that parties to collaborative R&D require personnel transfers in order to induce transfers of certain "tacit knowledge" (Teece 1986, Anand and Galetovic 2000). Of the 171 sets of contract examined here, just over 25% (44 RJV contracts) explicitly indicate the rights of at least one RJV member to visit the work site of another party who conducts R&D.

I assemble binary indicators for each of the three dimensions. The first indicator, labeled *Member R&D*, indicates whether or not at least one RJV member conducts R&D. (A positive indication does not rule out R&D efforts by entities external to the RJV such as a government or university lab.) The second indicator, *Third-party Licensing*, indicates whether or not R&D partners assign to some other party the right to license their Foreground Intellectual Property. R&D partners might, for example, formally incorporate the RJV and assign it rights to license intellectual property. The third indicator, *Visitation*, indicates whether or not at least one R&D partner has the right to visit the site at which some other party conducts R&D. That party might be an RJV member or an entity external to the RJV.

I apply the three binary indicators to probit analyses to discern differences between government-subsidized ventures and non-subsidized ventures I also subject NDA's on Background Intellectual Property and Foreground Intellectual Property to separate survival analyses (Cox regressions). Conceivably, the binary indicators and the duration of NDA's will also vary with the attributes of intellectual properties underlying each RJV as well as with the attributes of RJV partners themselves. It is well understood that attributes span many dimensions – dimensions such as the codifiability of intellectual property or the degree to which intellectual property is "tacit" (Contractor and Ra 2002, Winter 1987). It is also well understood that some parties will be better equipped than others to absorb and exploit another party's knowledge (Sampson 2004). While it is not likely that one could assemble controls that would allow one to precisely measure all attributes for each contract, one can assemble controls that go some way toward capturing these various dimensions.

All together, I assemble five dependent variables: the three binary indicators, the duration of NDA's applied to Background Intellectual Property, and the duration of NDA's applied to

Foreground Intellectual Property. I also assemble twelve independent variables, eleven of which are binary. Three of the binary variables indicate government entities: *ATP*, *DOD* (Department of Defense), and *All Other Government*. Five of the binary variables are two-digit SIC codes assigned to the technologies that were the subject of the RJV's. Only those SICs appearing more than 10 times in the dataset of 171 RJV's are included, but they are included in order to pick up some of the variation across attributes of the underlying intellectual property. The included SICs represent *Oil & Gas Extraction* (*SIC 13*), *Chemicals* (*SIC 28*), *Industrial and Commercial Machinery* (*SIC 35*), *Electronics* (*SIC 36*) and *Business Services* (*SIC 73*). I include another binary variable labeled *Pollution Abatement* to indicate whether or not the RJV technology pertains to pollution abatement. Two other binary variables elaborate the role of third-parties in collaborative R&D. The variables *Lab* and *University* indicate whether or not a government lab or a university contributed R&D efforts. Finally, I include a variable indicating the year in which the RJV made its NCRA filing (*File Year*). *File Year* controls for trends over time (if any) in the way parties craft NDA's.

Some readers may be wondering about differences between "equity joint ventures" and contractual arrangements that these same readers might recognize as "alliances." I exclude an indicator variable distinguishing equity joint ventures, because only four RJV's were organized as equity JVs. Finally, I did craft two other variables to isolate the effects of two entities that are represented more than ten times each in the set of 171 RJV's (not reported). RJV partners frequently contracted each of these two entities to conduct R&D, but inclusion of them in any of the survival analyses did not add information beyond what other variables (principally the industry variables) already contributed.

The government variables require some elaboration. The 20 ATP-sponsored ventures featured in the dataset made NCRA filings between 1989 and 1999. That ten-year interval leaves out ATP activity from the last decade, but it turns out that it largely conforms to the interval of ATP-ventures examined by Dyer et al. (2007). This could be important, because I will use the results presented here to qualify the principal conclusions featured in Dyer et al. (2007). In that paper the authors examine all ventures assembled between 1990 and 2001. Meanwhile, the NCRA filings of the 23 DOD-sponsored ventures in the dataset span a longer interval, 1985 through 2004. DOD-sponsored ventures tended to be driven by DOD demands for technologies. In contrast, the process of identifying ATP-sponsored ventures was more decentralized in that private parties had a greater hand in proposing R&D projects.

Table 1 indicates the distribution of the three binary contract dimensions across each of the eleven binary independent variables. It indicates, for example, that of 14 contracts that involved *Gas & Oil Extraction* (SIC 13), six (42.9%) involved some type of visitation rights. Five contracts involved R&D efforts by RJV members, which means that nine contracts exclusively involved R&D efforts by non-members. Specifically, these nine RJV's involved efforts by some entity or entities contracted by R&D members to undertake prescribed projects. None of the 14 contracts involved third-party licensing.

Now consider ATP-sponsored ventures. Of 22 such ventures, 18 (81.8%) involved R&D efforts by member firms, yet only two of the 22 contracts (9.1%) involved some type of visitation rights. The suggestion is plain: Parties to ATP-sponsored ventures tended to engage R&D efforts, but they engaged efforts in separate facilities as opposed to working side-by-side with researchers from other member firms. Thus far, the ventures appear to have involved little in the way of knowledge transfers. Contrast these results with all non-ATP ventures featured in the data set (not reported in Table 1). Less than half of the non-ATP ventures – only 64 of 149 ventures (43.0%) – involved member firm R&D efforts; the ATP-sponsored ventures involved heavier hands-on participation by member firms. Even so, non-ATP ventures involved visitation (42 of 149 ventures). Whether or not member firms engaged R&D efforts, more of them were permitted to visit the sites at which some party did engage important R&D.

ATP-sponsored ventures aside, other government-sponsored ventures appear, thus far, to have involved some volume of knowledge transfers. Over 30% of the ventures sponsored by either the DOD or "All Other" government entities featured visitation. DOD-sponsored ventures also tended to feature a relatively high volume of member R&D efforts (73.9%).

Now note an apparent "pollution abatement effect": Member firms tended to contract out R&D efforts in that only 12 of 55 ventures (21.8%) involved member R&D. Also, only four of the 55 ventures (7.3%) involved visitation. That is, member firms tended to assign discrete tasks to contractors who worked absent observation in their own facilities. The ventures appear to have involved little in the way of the transfer of knowledge assets. Rather, member firms simply pooled financial resources and paid an outside party to perform a prescribed task.

Tables 2 and 3 respectively summarize the duration of NDA's applied to Background Intellectual Property and Foreground Intellectual Property. The data feature NDA's of both zero duration and indefinite duration. The longest NDA's of definite duration for either Background Intellectual Property or Foreground Intellectual Property run 35 years. In 21 and 20 of the 171 contracts, respectively, the NDA's applied to Background Intellectual Property and Foreground Intellectual Property were indefinite.

The second column of Tables 2 and 3 indicates the "Average Duration" of NDA's across the various binary variables. This requires some explanation. Absent instances of indefinite duration, one might simply summarize the duration of NDA's by reporting averages and attending standard deviations. Yet, instances of indefinite duration frustrates this. One can, however, understand indefinite duration as a kind of truncation, and it turns out that methods of dealing with duration data are well equipped to accommodate such truncation.

For each subset of the contract data indicated by the eleven binary indicators, I apply a duration model that requires nothing more than estimation of a single parameter: a constant hazard rate. More generally, a hazard function constitutes one way of modeling the prospect of a single, discrete event occurring at a given instant in time, given the event has not yet occurred. The event of interest is the termination of an NDA at time *t*.

Appealing to the termination of an NDA as a single, discrete event enables us to appeal to the standard tools of "survival analysis" according to which the hazard rate $h(t) = f(t)/[1-F(t)]$ where $f(t)$ indicates a probability density function, $F(t)$ indicates the corresponding cumulative density function, and the term $1-F(t)$ indicates the probability that the duration of the NDA under examination exceeds *t*. of having reached time *t* without having realized any value.

Imposing a constant hazard rate $h(t) = \lambda$ amounts to imposing the exponential density function $f(t;\lambda) = \lambda e^{-\lambda t}$ and "survival function" $S(t;\lambda) = 1 - F(t;\lambda) = e^{-\lambda t}$. This allows us to express the corresponding likelihood function as

$$L = \prod_{\substack{finite \\ restrictions}} f(t_i;\lambda) \prod_{\substack{indefinite \\ restrictions}} S(t;\lambda) = \prod_{\substack{finite \\ restrictions}} \lambda e^{-\lambda t_i} \prod_{\substack{indefinite \\ restrictions}} e^{-\lambda t_i}$$

$$= \prod_{i=1}^{N} \left(\lambda e^{-\lambda t_i}\right)^{\delta_i} \left(e^{-\lambda t_i}\right)^{1-\delta_i}$$

where *i* indexes each contract in a set of *N* contracts and $\delta_i = \begin{cases} 0, & \text{NDA}_i \text{ is indefinite} \\ 1, & \text{NDA}_i \text{ is finite} \end{cases}$.

The corresponding log-likelihood is $\ln L = \sum_{i=1}^{N} \left(\delta_i \ln\lambda - \lambda t_i\right)$, and the maximum likelihood estimate of the hazard rate corresponds to $1/\lambda = \sum_{i=1}^{N} t_i \Big/ \sum_{i=1}^{N} \delta_i$. Note, that if there is no truncation (no NDA's of indefinite duration), then $\delta_i = 1$ for all *i* and a familiar result obtains: $1/\lambda = \sum_{i=1}^{N} t_i \Big/ N$, the average duration of the NDA's.

The "Average Duration" (years) reported in the first column of Table 2 corresponds to $1/\lambda = \sum_{i=1}^{N} t_i \Big/ \sum_{i=1}^{N} \delta_i$ where $t_i = 35$ for NDA's of indefinite duration. Standard errors are also reported. The other three columns indicate the minimum observed duration (almost always zero years), the maximum of the NDA's of definite duration ("Observed Maximum"), and the count of NDA's of indefinite duration ("Indefinite Duration").

Many formative results are apparent. The Chemicals/Electronics dichotomy obtains in the NDA's for Background Intellectual Property. The duration of NDA's corresponding to *Chemicals* (SIC 28) "average" 10.85 years, whereas for *Electronics* (SIC 36) the average is 3.92 years. The longest NDA for electronics was five years, whereas the longest NDA of definite duration for *Chemicals* was 35 years. Furthermore, 7 of the NDA's with respect to *Chemicals* were indefinite. None of the NDA's for *Electronics* were indefinite.

Government-sponsored ventures appear to assign to Background Intellectual Property NDA's of longer-than-average duration. They average 17.71 years, whereas the average across the entire dataset of 171 contracts is 8.99 years. Meanwhile, ventures involving R&D inputs from *Federal Labs* do not feature such long NDA's. Those NDA's average 10.09 years.

Table 3 yields some parallel results and some different results pertaining to Foreground Intellectual Property. The Chemicals/Electronics dichotomy is more pronounced. Meanwhile, the distinction between ventures sponsored by the ATP and DOD and all other contracts is much diminished. In contrast, the 20 ventures involving *All Other Government* entities tend to impose

NDA's of very long duration on Foreground Intellectual Property. They "average" 31.64 years, whereas the average across the entire dataset is 9.07 years.

Tables 2 and 3 enable elaboration of the apparent "pollution abatement effect." Ventures involving the development of pollution abatement technologies tend to feature NDA's of shorter-than-average duration on Background Intellectual Property and NDA's of average duration on Foreground Intellectual Property. The results are consistent with a view that such ventures tend to involve less in the way of important knowledge inputs and more in the way of task-oriented R&D around which member firms pool financial resources to cover the costs of contracting the R&D efforts of an outside party.

4. Results

The descriptive statistics featured in Tables 1, 2, and 3 may suggest a number of results, but the succeeding five tables feature more systematic (i.e., regression) analyses, though I must stress that the results I illuminate involve correlations between the "dependent" and "independent" variables, not causal relationships. Specifically, I am not examining "treatment effects." The variables *ATP* and *DOD*, for example, do not identify treatments that induce certain effects, although I will indulge in some abuse of language and speak of such things as an "ATP effect" or "DOD effect." Even so, all of the results reported here are more descriptive in that they indicate how ventures sponsored by such entities at the ATP or DOD tended to organize themselves.

The first three tables present probit analyses pertaining to the various binary dimensions of contract. The last two tables present "survival analyses" of the NDA's. I model the duration of NDA's with the Cox relative risk model. In its simplest form, the Cox model corresponds to a proportional hazards model by which the hazard rate conforms to $\lambda(t; x_i) = \lambda_0(t)e^{x_i'\beta}$ where i indexes each RJV, x_i indicates a vector of covariates measured at time $t = 0$, β is a vector of regression coefficients, and $\lambda_0(t)$ indicates an arbitrary baseline hazard rate common to all RJV's. I separately estimate Cox models for NDA's on Background Intellectual Property and NDA's on Foreground Intellectual Property. In both models I accommodate NDA's of indefinite duration by treating them as survival times known only to have exceeded 35 years.

While the Cox model can be adapted to accommodate non-proportional hazards, I only report results for Cox proportional hazard models. There is some evidence that hazards may not be proportional across the two values of the covariate *University*, but all of the results obtain in Cox regressions that either accommodate or ignore the potential for non-proportional hazards. I also note that all of the qualitative results I report are robust to estimation by each model in the nested sequence of fully parametric models comprised of the gamma, Weibull, and exponential hazard models.[10]

[10] Estimating Cox models amounts to ignoring the baseline hazard rate and applying maximum likelihood to the remaining part of the model to yield a 'partial likelihood.' One technical point remains: the simplest Cox models apply to survival data that feature unique survival times. The partial likelihood estimation must be adapted to accommodate ties in the survival data. While there is no unique way to accommodate ties, I follow the suggestion of Kalbfleish and Prentice (2002, pp. 105-106) and apply the Efron approximation of the average partial likelihood.

Given a covariate $x_{ij} \geq 0$ and coefficient β_j, a coefficient estimate $\hat{\beta}_j$ would indicate a "hazard ratio" $e^{x_{ij}\hat{\beta}_j}$ which is a hazard rate of proportion $e^{x_{ij}\hat{\beta}_j}$ of the baseline hazard rate $\lambda_0(t)$. Positive coefficients indicate hazard rates that exceed the baseline rate and thus imply shorter survival times (NDA's of shorter duration). Negative coefficients indicate smaller hazard rates and therefore imply longer survival times (NDA's of longer duration).

The probit analyses and survival analyses illuminate four sets of results. First, the Chemicals/Electronics dichotomy bears out in the survival analyses. The duration of NDA's involving *Chemicals* are significantly longer than those involving *Electronics*. The results are consistent with hypothesis that more appropriable intellectual properties map into NDA's of longer duration. The "ATP Effect" comes second. ATP-sponsored ventures tend not to involve visitation and tend to involve the input of Background Intellectual Properties that are highly appropriable. All together, the results suggest that ATP-sponsored ventures tend to involve little in the way of spillovers of knowledge inputs. Third, there is a parallel but less elaborate "DOD Effect." DOD-sponsored ventures also feature highly appropriable knowledge inputs in that, like Chemicals, the duration of NDA's on Background Intellectual Property tend to be long. Fourth, and finally, the "Pollution Abatement Effect" bears out. Ventures involving pollution abatement technologies tended to concentrate on cost-sharing by means of contract R&D. These ventures involved little in the way of the sharing of knowledge inputs.

I take these results up in turn:

Result 1: The Chemicals/Electronics dichotomy bears out in the duration data.

Tables 7 and 8 feature the Cox regressions of NDA's against the industry codes and the government indicators. Both tables feature a set of three nested regressions with the first one illuminating the relationship of ATP sponsorship and DOD sponsorship to the duration of NDA's involving Background Intellectual Property and the second table illuminating the relationship of *All Other Government* entities to the duration of NDA's involving Foreground Intellectual Property. Positive coefficient estimates indicate higher hazard rates (and therefore shorter duration), and negative coefficient estimates indicate lower hazard rates (and therefore longer duration).

In all six Cox regressions, the coefficient estimates pertaining to *Chemicals* is significantly lower than the coefficient estimates pertaining to *Electronics*. Likelihood ratio tests suggest that specification (3) in each table adds little information that is not already captured by specification (2) of each table. The difference between the coefficient estimates is 1.068 – a difference significant at the 1% confidence level – which in turn implies that *Electronics* features a hazard rate with respect to Background Intellectual Property that is $e^{1.068} = 2.911$ times greater than the *Chemicals* hazard rate. Specification (2) of Table 8 yields a similar result. The difference in coefficient estimates is significant at the 1% level and implies a hazard rate $e^{1.023} = 2.780$ times greater than the *Chemicals* hazard rate.

Result 2: ATP-sponsored ventures may have involved the sharing of knowledge outputs, but they involved little in the way of the transfer of knowledge inputs. The result delimits the conclusions of ATP-sponsored research.

Tables 4, 5, and 6 present results from the binary probit analyses. The feature results pertaining to *Visitation*, *Member R&D*, and for the interacted variable *Member R&D* Visitation*. I do not report results for *Third-party Licensing*, because they contributed little information.

These tables feature marginal effects rather than coefficient estimates. Likelihood ratio tests suggest that specifications (2) in Tables 4 and 5 as well as specification (3) in Table 6 constitute the best specifications.

Table 4 indicates important correlations between Visitation and the variables *File Year, ATP*, and *Pollution Abatement*. *DOD* and *All Other Government* are inconsequential, but specification (2) indicates that ATP-sponsored ventures featured visitation 19.5% less frequently than the baseline venture, a result that is significant at the 1% level. *Machinery* (SIC 35), *ATP* and *Pollution Abatement* are featured prominently in Table 5 with respect to *Member R&D*. Specification (2) indicates that ATP-sponsored ventures depended on member R&D efforts 37.1% less frequently than the baseline venture, a result that is also significant at the 1% level.

Now consider the interaction term *Member R&D*Visitation*. The term identifies 27 instances in which RJV's featured visitation rights and at least one member firm contributed important R&D efforts. Such instances should reflect circumstances more conducive to the transfer of knowledge inputs or knowledge outputs. A modest, negative ATP result obtains: ATP-sponsored ventures featured the combination of member R&D efforts and visitation by other member firms 8.4% less frequently than the baseline venture.

Now consider the duration of NDA's. Specification (2) of Table 7 indicates that ATP-sponsored ventures imposed NDA's on Background Intellectual Property characterized by hazard rates $e^{-0.535} = 58.6\%$ as large as the hazard rate prevailing in the baseline venture, a result that is significant at the 1% level. Meanwhile, Table 8 indicates no discernible correlation between *ATP* and the duration of NDA's on Foreground Intellectual Property.

The survival analysis suggests that ATP-sponsored ventures tended to feature Background Intellectual Properties more like *Chemicals* than *Electronics*.: more amenable to appropriation and less amenable to unintended spillover. Meanwhile, the results pertaining to *Visitation* and *Member R&D*Visitation* suggest that ATP-sponsored ventures were less likely by design to be motivated by the prospect of important transfers of knowledge inputs.

These results are interesting, because they allow one to qualify the conclusions of ATP-sponsored research. Dyer et al. (2000), for example, examined 142 ATP ventures organized between 1990 and 2001. They observe that ATP ventures appear more "vertical" than "horizontal" in that member firms purportedly contributed complementary assets and capabilities, and they further suggest that these ventures were focused on "knowledge sharing."

The results presented here are consistent with the findings of Dyer et al. (2000), but the results delimit what knowledge sharing likely entailed. It may have entailed the sharing of knowledge outputs – a point suggested by other ATP-sponsored research (Feldman and Kelley 2003) – but there is little indication that member firms were sharing knowledge inputs. They were certainly providing the rights-of-way member firms required to collaborate, but the ventures do not look like the ventures that really did require transfers of knowledge inputs – ventures like the one between Human Genome Sciences and SmithKline Beecham.

Result 3: DOD-sponsored ventures have involved knowledge inputs that are less amenable to spillover.

The one salient *DOD* result parallels the counterpart *ATP* result: DOD-sponsored ventures imposed NDA's on Background Intellectual Property characterized by hazard rates $e^{-0.631} = 53.2\%$ as large as the hazard rate prevailing in the baseline venture, a result that is also significant at the 1% level. Table 8 indicates no discernible correlation between *DOD* and the duration of NDA's on Foreground Intellectual Property.

Again, the survival analysis suggests that DOD-sponsored ventures tended to feature Background Intellectual Properties more like *Chemicals* than *Electronics*.: more amenable to appropriation and less amenable to unintended spillover.

Result 4: Ventures involving the development pollution abatement technologies concentrate on cost-sharing, not on the transfer of knowledge assets.

The results relevant to *Pollution Abatement* derive entirely from the probit analyses. The survival analyses indicate no discernible correlations between the duration of NDA's and *Pollution Abatement*. Specification (2) of Table 4 indicates that ventures organized around developing pollution abatement technologies featured visitation 31.5% less frequently than the baseline venture. Specification (2) of Table 5 indicates that *Pollution Abatement* featured *Member R&D* 36.3% less frequently than the baseline venture. Finally, Specification (3) if Table 6 indicates that these same ventures featured the combination of member R&D efforts and visitation 21.6% less frequently than the baseline venture. All of these results are significant at the 1% level.

The results are consistent with Pollution Abatement involving little in the way of member firm R&D efforts, little in the way of knowledge inputs by member firms, and more in the way of sharing the costs of contracting out R&D efforts to a party external to the venture.

5. Conclusion

How do private entities exploit government programs to support R&D? The paper examines 171 research joint ventures identified in NCRA filings made between 1984 and 2009. While the NCRA is itself an important government program, it turns out that the data extracted from NCRA filings reveal information about other government programs. Precisely one-third of the

171 contracts (57) involved RJV's that received subsidies from various federal programs as well as from a few state programs. Another 13 involved R&D efforts contributed by federal labs.

The two bodies of programs best represented in the data are the Advanced Technology Program and various Department of Defense programs including DARPA, the Defense Advanced Research Projects Agency. The most important results in this paper amount to comparing and contrasting the organization of ventures sponsored by the ATP and the DOD to the "baseline" venture represented by the entire body of data.

Ventures sponsored by the ATP and the DOD appear much like ventures organized around the development of "Chemicals." Intellectual Properties involving chemicals have been long understood to be more appropriable than other bodies of intellectual property. Indeed, a contrast is often made between "Chemicals" and " Electronics," with the former being amenable to all types of remedies to unintended spillovers and the latter being unavoidably subject to spillovers. The ATP and DOD-sponsored ventures featured Background Intellectual Properties that were subject to more restrictive protections. Specifically, they were subject to non-disclosure agreements of long duration suggesting that the parties to such ventures tended to contribute the kinds of intellectual properties that were less susceptible to spillover.

Further results suggest that ATP-sponsored ventures tended to involve projects that did not require transfers of knowledge inputs. Instead, member firms would dispatch R&D tasks in their independent facilities. This is contrast to the long-running, non-subsidized collaboration between Human Genome Sciences and SmithKline Beecham. SmithKline Beecham reserved the right to detail personnel to HGS facilities so that these same personnel might absorb some of the HGS know-how SKB would then need to develop new drug therapies. Thus, whereas transfers of knowledge inputs was an explicitly designed feature of the HGS/SKB collaboration, such transfers were explicitly precluded in ATP-sponsored ventures.

That is not to say that ATP-sponsored ventures did not involve important knowledge transfers. The evidence presented here and the evidence presented in a body of ATP-sponsored research are consistent with the proposition that ATP-sponsored ventures were designed around sharing the knowledge outputs of collaborative R&D.

The NCRA data reveal other discrete patterns. Specifically, a large of ventures (55 of 171) involved the development of pollution abatement technologies. The structures of the contracts corresponding to these ventures are amenable to a simple interpretation about how these ventures worked. They involved little in the way of R&D efforts by member firms. Rather, member firms tended to contract out to parties external to the venture well-defined discrete tasks. The purpose of the venture amounted to cost-sharing: member firms would share the costs of compensating contract researchers. Further, these ventures involved little in the way of transfers of knowledge inputs.

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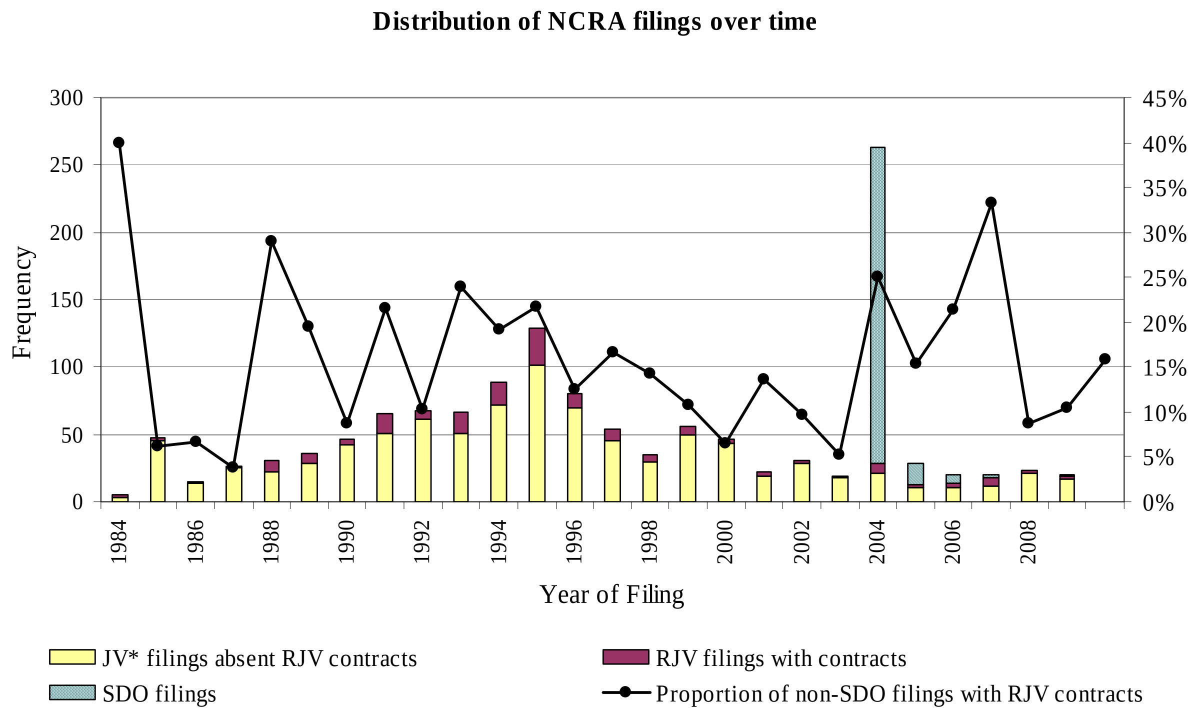
Figure 1



* The indication 'JV' in place of 'RJV' reflects the inclusion of 'production joint ventures' starting in 1993.

Table 1

Contract Dimensions:
Visitation, Member R&D and Third-party Licensing

	Observations	Visitation	Member R&D	Third-party Licensing
SIC 13 - Gas & Oil Extraction	**14**	**6** 42.9%	**5** 35.7%	**0** 0.0%
SIC 28 - Chemicals	**41**	**8** 19.5%	**20** 48.8%	**1** 2.4%
SIC 35 - Machinery	**37**	**7** 18.9%	**7** 18.9%	**4** 10.8%
SIC 36 - Electronics	**13**	**3** 23.1%	**11** 84.6%	**3** 23.1%
SIC 73 - Business Services	**26**	**7** 26.9%	**15** 57.7%	**6** 23.1%
Government Sponsorship	**57**	**13** 22.8%	**39** 68.4%	**6** 10.5%
ATP	**20**	**2** 9.1%	**18** 81.8%	**1** 4.5%
DOD	**23**	**7** 30.4%	**17** 73.9%	**4** 17.4%
All Other Government	**20**	**6** 30.0%	**10** 50.0%	**5** 25.0%
Federal Lab	**13**	**5** 38.5%	**9** 69.2%	**2** 15.4%
University	**37**	**10** 27.0%	**17** 45.9%	**2** 5.4%
Pollution Abatement	**55**	**4** 7.3%	**12** 21.8%	**4** 7.3%
All Contracts	**171**	**44** 25.7%	**82** 48.0%	**16** 9.4%

Table 2

Duration of NDA's – Background Intellectual Property

	N (obs.)	Average* Duration (years)	Minimum Duration (years)	Observed Maximum (years)	Indefinite NDA's (count)
SIC 13 - Gas & Oil Extraction	**14**	**3.85**	**0**	**5**	**1**
		1.32			7.1%
SIC 28 - Chemicals	**41**	**10.85**	**0**	**35**	**7**
		1.19			17.1%
SIC 35 - Machinery	**37**	**6.49**	**0**	**10**	**2**
		1.18			5.4%
SIC 36 - Electronics	**13**	**3.92**	**0**	**5**	**0**
		1.32			0.0%
SIC 73 - Business Services	**26**	**12.10**	**0**	**35**	**5**
		1.24			19.2%
Government Sponsorship	**57**	**17.71**	**0**	**20**	**15**
		1.17			26.3%
ATP	**20**	**17.53**	**0**	**10**	**5**
		1.29			25.0%
DOD	**23**	**15.44**	**0**	**20**	**5**
		1.27			21.7%
All Other Government	**20**	**22.15**	**0**	**5**	**7**
		1.32			35.0%
Federal Lab	**13**	**10.09**	**0**	**10**	**2**
		1.35			15.4%
University	**37**	**10.13**	**0**	**35**	**5**
		1.19			13.5%
Pollution Abatement	**55**	**5.15**	**0**	**20**	**3**
		1.15			5.5%
All Contracts	**171**	**8.99**	**0**	**35**	**21**
		1.09			12.3%

* The "average" corresponds to $\sum_{i=1}^{N} t_i \Big/ \sum_{i=1}^{N} \delta_i$ where $\delta_i = 1$ indicates finite NDA (zero otherwise) and $t_i = 35$ for NDA's of indefinite duration.

Table 3

Duration of NDA's – Foreground Intellectual Property

	N (obs.)	Average* Duration (years)	Minimum Duration (years)	Observed Maximum (years)	Indefinite NDA's (count)
SIC 13 - Gas & Oil Extraction	**14**	**2.86**	**1**	**5**	**0**
		1.31			0.0%
SIC 28 - Chemicals	**41**	**18.13**	**0**	**35**	**10**
		1.20			24.4%
SIC 35 - Machinery	**37**	**4.46**	**0**	**10**	**2**
		1.18			5.4%
SIC 36 - Electronics	**13**	**4.54**	**3**	**5**	**0**
		1.32			0.0%
SIC 73 - Business Services	**26**	**12.43**	**0**	**20**	**5**
		1.24			19.2%
Government Sponsorship	**57**	**15.45**	**0**	**20**	**13**
		1.16			22.8%
ATP	**20**	**11.94**	**0**	**10**	**3**
		1.27			15.0%
DOD	**23**	**10.50**	**0**	**20**	**3**
		1.25			13.0%
All Other Government	**20**	**31.64**	**0**	**10**	**9**
		1.35			45.0%
Federal Lab	**13**	**10.45**	**0**	**10**	**2**
		1.35			15.4%
University	**37**	**9.48**	**0**	**10**	**4**
		1.19			10.8%
Pollution Abatement	**55**	**8.37**	**0**	**20**	**6**
		1.15			10.9%
All Contracts	**171**	**9.07**	**0**	**35**	**20**
		1.08			11.7%

* The "average" corresponds to $\sum_{i=1}^{N} t_i \Big/ \sum_{i=1}^{N} \delta_i$ where $\delta_i = 1$ indicates finite NDA (zero otherwise) and $t_i = 35$ for NDA's of indefinite duration.

Table 4

Probit Analysis – Visitation

Visitation	(1)	(2)	(3)
SIC 13 - Gas & Oil Extraction	**0.085**	**0.068**	**0.055**
	0.144	0.140	0.139
SIC 28 - Chemicals	**-0.001**	**0.025**	**0.018**
	0.102	0.106	0.107
SIC 35 - Machinery	**-0.037**	**-0.043**	**-0.046**
	0.099	0.098	0.098
SIC 36 - Electronics	**-0.106**	**-0.094**	**-0.076**
	0.095	0.098	0.106
SIC 73 - Business Services	**-0.088**	**-0.078**	**-0.085**
	0.083	0.084	0.082
File Year	**0.018*** **	**0.017*** **	**0.018*** **
	0.007	0.006	0.007
ATP		**-0.188*** **	**-0.195*** **
		0.054	0.054
DOD			**-0.079**
			0.084
All Other Government			**0.014**
			0.100
Federal Lab			**0.092**
			0.134
University	**0.043**	**0.042**	**0.053**
	0.082	0.079	0.082
Pollution Abatement	**-0.304*** **	**-0.315*** **	**-0.320*** **
	0.057	0.057	0.058
Likelihood	**-83.31**	**-80.59**	**-80.04**

The notations ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 5

Probit Analysis – Member R&D

Member R&D	(1)	(2)	(3)	(4)
SIC 13 - Gas & Oil Extraction	**-0.350*** 0.105	**-0.348*** 0.113	**-0.320** 0.125	**-0.323** 0.127
SIC 28 - Chemicals	**-0.037** 0.122	**-0.054** 0.126	**-0.032** 0.126	**-0.008** 0.123
SIC 35 - Machinery	**-0.366*** 0.096	**-0.370*** 0.097	**-0.360*** 0.099	**-0.356*** 0.099
SIC 36 - Electronics	**0.164** 0.184	**0.150** 0.186	**0.100** 0.185	**0.108** 0.185
SIC 73 - Business Services	**-0.168** 0.125	**-0.187** 0.124	**-0.203** 0.125	**-0.195** 0.127
File Year	**-0.007** 0.008	**-0.007** 0.008	**-0.006** 0.008	**-0.006** 0.008
ATP		**0.371*** 0.108	**0.401*** 0.103	**0.391*** 0.106
DOD			**0.230*** 0.127	**0.235*** 0.129
All Other Government				**-0.097** 0.146
Federal Lab				**0.146** 0.186
University	**-0.065** 0.099	**-0.066** 0.101	**-0.106** 0.105	**-0.116** 0.107
Pollution Abatement	**-0.387*** 0.084	**-0.363*** 0.089	**-0.339*** 0.093	**-0.337*** 0.093
Likelihood	**-96.59**	**-92.83**	**-91.34**	**-90.89**

The notations ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 6

Probit Analysis – Member R&D*Visitation

Member R&D*Visitation	**(1)**	**(2)**	**(3)**
SIC 13 - Gas & Oil Extraction	**-0.031**	**-0.041**	**-0.034**
	0.070	0.063	0.063
SIC 28 - Chemicals	**0.059**	**0.078**	**0.099**
	0.082	0.085	0.090
SIC 35 - Machinery	**-0.029**	**-0.033**	**-0.024**
	0.067	0.064	0.063
SIC 36 - Electronics	**-0.098****	**-0.094****	**-0.090****
	0.043	0.042	0.041
SIC 73 - Business Services	**-0.088***	**-0.076**	**-0.078***
	0.047	0.049	0.045
File Year	**0.003**	**0.003**	**0.002**
	0.005	0.005	0.005
ATP		**-0.085****	**-0.084****
		0.040	0.038
DOD			**0.013**
			0.073
All Other Government		**-0.060**	**-0.095*****
		0.052	0.033
Federal Lab			**0.252***
			0.151
University	**-0.018**	**-0.014**	**-0.034**
	0.054	0.052	0.044
Pollution Abatement	**-0.227*****	**-0.230*****	**-0.216*****
	0.045	0.045	0.044
Likelihood	**-62.88**	**-61.36**	**-59.38**

The notations ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 7

Duration of NDA's – Background Intellectual Property

Cox Regression Coefficients

Background Intellectual Property	**(1)**	**(2)**	**(3)**
SIC 13 - Gas & Oil Extraction	**1.222*** 0.471	**1.029**** 0.479	**1.006**** 0.476
SIC 28 - Chemicals	**0.031** 0.215	**-0.013** 0.218	**0.053** 0.214
SIC 35 - Machinery	**0.024** 0.303	**-0.070** 0.296	**-0.187** 0.322
SIC 36 - Electronics	**0.816***** 0.204	**1.055***** 0.225	**1.076***** 0.227
SIC 73 - Business Services	**0.180** 0.270	**0.231** 0.286	**0.235** 0.286
File Year	**-0.026*** 0.016	**-0.028*** 0.015	**-0.026*** 0.016
ATP		**-0.535**** 0.246	**-0.506**** 0.229
DOD		**-0.631**** 0.246	**-0.683**** 0.268
All Other Government			**-0.513** 0.334
Federal Lab			**0.563** 0.371
Pollution Abatement	**0.198** 0.256	**0.139** 0.262	**0.265** 0.265
Likelihood	**-444.21**	**-440.90**	**-439.14**

The notations ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 8

Duration of NDA's – Foreground Intellectual Property

Cox Regression Coefficients

Foreground Intellectual Property	(1)	(2)	(3)
SIC 13 - Gas & Oil Extraction	**0.683**** 0.328	**0.610*** 0.333	**0.547** 0.342
SIC 28 - Chemicals	**-0.655***** 0.227	**-0.590***** 0.223	**-0.562**** 0.231
SIC 35 - Machinery	**0.478** 0.316	**0.413** 0.330	**0.409** 0.326
SIC 36 - Electronics	**0.434**** 0.202	**0.433**** 0.205	**0.543**** 0.225
SIC 73 - Business Services	**-0.067** 0.303	**0.124** 0.294	**0.171** 0.318
File Year	**-0.006** 0.016	**-0.004** 0.016	**-0.002** 0.016
ATP			**-0.262** 0.261
DOD			**-0.292** 0.237
All Other Government		**-0.764**** 0.371	**-0.847**** 0.390
Federal Lab			**0.297** 0.353
Pollution Abatement	**-0.058** 0.249	**-0.018** 0.258	**-0.061** 0.260
Likelihood	**-452.45**	**-449.46**	**-448.46**

The notations ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.