Understanding When Universities and Firms Form RJVs: The Importance of Intellectual Property Protection.*

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Abstract

During the past 20 years we have witnessed an increase in joint research between universities and firms. Nevertheless, this increase, which is largely attributed to the Bayh-Dole Act, has fallen short of expectations. This paper examines the conditions under which a firm will find it profitable to form an RJV with a university. My results indicate that firms, which work on new-technologies, are more likely to form such partnerships. The reason is that these firms optimally choose minimal IP protection (lower profits), in effect sharing their innovation, so as to benefit from increased knowledge spillovers. Thereby, the opportunity cost of joining an RJV for firms (and universities) working on mature technologies is greater, making such partners unlikely candidates for RJVs.

Keywords: Intellectual property, RJV.

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1 Introduction

In the early 1980's, the Bayh-Dole Act enabled universities to patent their innovations easier than before. The purpose of the Act was to foster US innovative activity, especially between firms and universities, at a time when fears were mounting that the US was a technological laggard compared to Japan. There is no doubt that universities and firms had been jointly doing research well before the Bayh-Dole Act, Rosenberg and Nelson (1994). Nevertheless, the Act was successful in bridging many barriers between firms and universities, leading them to form Research Joint Ventures (RJV). Indeed there seems to be an increase in RJVs, not only between US firms and US universities, Baldwin and Link (1998), but, as figure 1 displays, between EU firms and US universities as well, Link and Vonortas (2002). However, as Hall, Link and Scott (2000) note, this increase is not as high as one would have anticipated. In explaining this shortfall in RJVs, Hall, Link and Scott (2000) stressed (among other reasons) the importance of Intellectual Property (IP) protection in setting obstacles to the formation of RJVs.

The aim of this paper is to try to understand under what conditions firms are likely to form an RJV with a university and when can IP issues raise barriers. The theoretical literature on this issue is rather slim. With the exception of Beath et al. (2001) and Poyago-Theotoky et al. (2002), I am not aware of any other work, which studies the potential barriers in the formation of RJVs.

The thesis advanced in this paper is that firms and universities, whose research is on new-technologies,[1] will find it easier to form such RJVs. A finding as such seems to be in line with evidence offered by Hall, Link and Scott (2001) and Link and Vonortas (2002). In explaining the above proposition, the paper stresses the importance of the degree of IP protection. Specifically, the paper shows that the optimal policy for a firm (university) that conducts research on a fast evolving and not well-understood technology (i.e. a new-technology) is to share it, by choosing

[1] Technologies that are closer to science and evolve faster than well-developed and well-understood technologies.

to have a low degree of IP protection.[2] For example, when Bell Laboratories invented the transistor, which is a classic example of a new-technology, they licenced their patent to most competitors. At the time, Bell Laboratories recognized that they should forego some of their profits to benefit from the extended knowledge produced by spillovers.[3]

Keeping this in mind, when a firm (university) chooses to join an RJV, the firm must also account for its opportunity cost (the profits that it sacrifices by halting the research that it conducts on its own),[4] and the greater this opportunity cost is, the harder it will be for a firm to enter such a research partnership. However, as the above paradigm emphasizes, "mature" technologies will generate greater profits, because the firm does not have to share them. Thus, the opportunity cost for firms that already work on "mature" technologies will be greater. Thereby, firms and universities which conduct research on new-technologies will incur a lower opportunity cost, making them the most likely participants of an RJV. This finding is reinforced if one is to assume that universities concentrate their research only on new technologies.[5]

This line of thinking suggests that a large firm, operating many different research projects at the same time (thus being most likely to work on new-technologies among other things), should find it easier to form an RJV, because it would have a lower opportunity cost. This accords with the evidence presented by Caloghirou, Vorontas and Tsakanikas (2000), who find that firms that sell on average over 1 billion Euros tend to cooperate much more with universities.

In what follows, section 2 introduces the "technology generating" function, section 3 describes

[2] This argument is similar to Ben-Shahar and Jacob (2001). However, in their study, the innovator may optimally choose a low IP protection policy to lock-in other innovators, who will be using his technology to innovate and hence monopolize the market.

[3] In an interview, the head of Bell Laboratories recognized that what they had invented was beyond their capacity. So they licenced it, for a small amount, hoping that their invention would bring returns in the form of "angel dust". For a detailed account of the invention of the transistor see Rosenberg (1994), Mowery and Rosenberg (1989), and Nelson (1962).

[4] The firm (university) will stop its own similar research to avoid duplication. However, this does not imply that the firm (university) will halt its research altogether.

[5] Such an assumption is made by Beath et al. (2001).

demand, while section 4 explains the maximization problem of the innovator, to be followed by sections 5 and 6 that find the optimal degree of IP protection and the conditions under which an RJV will be formed.

2 Technology

2.1 An overview and some examples

In this section I will define, and provide examples, of the terms (such as innovation, RJV, university) that I will henceforth be using. In addition, I will present a summary of the way that individual innovators generate innovations and their objectives (the mathematical definitions will be provided in the sections that follow).

Specifically, heterogeneous innovators (firms) create patentable innovations, with a patent length of at least 2 years, through a discrete time technology generation process. At each point t in time, each innovator i creates an innovation, $\Delta A_{t,i}$, "an invention [which in my model becomes an innovation, a marketed technological advance] is a new means of achieving some function not obvious beforehand to someone skilled in the prior art", Kline and Rosenberg (1986).[6] The sum of the innovations created by the innovator up to that time, makes the innovator's technology $A_{t,i}$. This is similar to many different quality ladders,[7] each one representing only one technology.[8]

Each innovator conducts research on only one technology. The technology that each innovator is working on will be a substitute to the technologies that the rest of the innovators are working on. In the context of a "PC" environment, one can think of such substitute technologies as the work of many individual innovators who at the same time try to create a better "MP3 player", or a better "Media Player". In this setting, the knowledge created by each innovator would be potentially beneficial to the research carried out by all other innovators in the form of

[6] The brackets were not included in the original.

[7] See Grossman and Helpman (1991).

[8] There is a considerable literature which explores the time technology generation process in situations where the R&D investment of the firm endogenously shapes technology. For a review see Baldwin and Scott (1987).

knowledge spillovers; however, some form of tacit knowledge will be assumed, which does not allow an innovator to fully appropriate such spillovers. These knowledge spillovers are created when the innovator patents his innovation. Thereby, the work carried on the "MP3 player" can be beneficial to the innovator working on the "Media player".[9] The objective of each innovator is to create a better technology, since, as it will become apparent in later sections, one increases the demand for his technology by improving it further.

I define patent breadth as the amount that an innovator can reinnovate around the technology of any other innovator (without being found guilty of copying one's technology) and thus use it in his research, in the form of knowledge spillovers, without paying any property rights. The larger the patent breadth is, the harder it is for an innovator to fully reinnovate around one's technology. In what follows, I will assume that if the patent breadth is equal to 1, then innovator i must make full use of the technology created by innovator j, $j \neq i$, similarly, if the patent breadth is 0, then innovator i can freely copy the technology created by innovator j, without paying any property rights.[10] Based on the assumptions provided in the above paragraph, the patent breadth can neither be 0, nor 1. Specifically, having assumed the existence of tacit knowledge, the patent breadth cannot be equal to 0, because even if innovator j could freely appropriate the innovation of innovator i, he would still find it impossible to use it as well as its inventor. In addition, one should cancel out full IP protection, because in reality, due to spillovers, such a thing does not exist.[11]

[9] Thereby, the technologies generated by the innovators are substitutes which generate spillovers that are complements. This assumption attempts to capture the multidimensional nature of innovation, where knowledge spillovers can be beneficial even though they may have been generated by a technology that is a substitute. This accords with the evidence offered by Hall and Ziedonis (2001), who study the microprocessor's industry, noting that firms use overlapping technologies, many of which have been discovered by other firms who share the same market.

[10] My definition of patent breadth corresponds to that of Denicolo (1996).

[11] There is a large empirical literature pointing to this. For example, the research of Pakes and Shankerman (1979), has identified the effect that spillovers, diffused from major research centers (such as universities), have in fostering innovation. For the effects of academic research on innovation see Mansfield (1995), Jaffe (1989) and

In this framework, universities are research centers that specialize in both new and "mature" technologies. Through the term new-technology I imply a technology that is close to science. Such technologies have a large developing horizon, and they tend to move faster than "mature" and well understood technologies. A general example of such a technology would be software. An RJV will be a partnership between the firm and the university, a partnership in which both partners decide in advance on how to split the gains and the cost of their research. Hence, I will assume that they form a very simple agreement, where each partner appropriates a set percentage of either gains and cost (this percentage does not have to be the same for either gains and cost).

For an innovator to innovate, he needs knowledge spillovers. However, unless one is willing to assume that all innovators are homogeneous in their innovative capacity, the knowledge spillovers generated by one innovator should not have the same effect on one's research, as those created by another innovator. This generates the problem of discriminating among the spillovers-generating capacities of many innovators, each working on different technologies. Accordingly, I will assume that a patent race takes place, in which each innovator races against himself in order to reach a set "target". In the setting of the "Windows" environment, a "target" could be the demand for an "MP3 player" that has double compressing ability. The ability of the innovator who works on the "MP3 player" to create such a player, will determine how useful his spillovers are to all the other innovators.

2.2 Technology generation

Technology is produced by risk neutral innovators, who employ a specific "technology generating" function. Specifically, there exist a continuum of innovators, operating in an economy that lacks a credit market, and faces no population growth, who create innovations $\Delta A_{t,i}$, using knowledge

Zucker, Darby, and Armstrong (1998). In addition, Jaffe (1986) displayed the importance of the R&D spillovers, which are generated using a local pool of R&D, on the patent productivity of a firm. Spatial models as such can be found in Audretsch and Feldman (1996) and Kao, Chiang and Chen (1999).

spillovers s, as well as some funding through past profits $\pi_{t-1,i}$.[12] However, accounting for the lag between the publication of the patent and the time that it spillovers into research, Pakes and Schankerman (1979), innovators will be using s_{t-1}. Overall, the innovations created by innovator i, $i \in [0, n]$, are generated through the following "technology generating" function,

$$\Delta A_{t,i} = s_{t-1}\pi_{t-1,i} + \upsilon_i, \quad \upsilon_i = N(0, \sigma), \quad i \in [0, n] \tag{1}$$

The sum of the $\Delta A_{t,i}$, is a distinct technology line $A_{t,i}$, which is created by innovator i, having the following initial condition for $A_{t,i}$, $A_{0,i} > 0$, and no initial funding ($\pi_{-1,i} = 0$). Hence, $A_{t,i} = A_{0,i} + \sum_{0}^{t} \Delta A_{t,i}$. Equation (1) implies that s_{t-1}, π_{t-1} are substitutes that carry the same weight. Even though, this is a "convenient" simplification, there is no consensus among economists regarding the effect that spillovers have. Specifically, depending on the author, spillovers can account for 15% to 40% of an innovation, Griliches (1998). Furthermore, equation (1) suggests that in the absence of spillovers there is no $\Delta A_{t,i}$ no matter how big $\pi_{t-1,i}$ is. This assumption corresponds to the idea that no innovation can be created in vacuum and spillovers are essential and necessary when creating an innovation.

In equation (1), υ_i is a Normally distributed component with mean 0 and variance σ, where σ is assumed to be exogenous. Due to υ_i, innovators who have similar (s_{t-1}, π_{t-1}) will not produce innovations of the same magnitude. In that respect, υ_i represents the innovator's ability to innovate. Since υ_i, can attain negative values it is possible for $\Delta A_{t,i}$ to be less than zero. If this turns out to be the case, it implies that research has followed a wrong path producing a technology $A_{t,i}$ that is less than past technology $A_{t-1,i}$. Accordingly, the innovator will not make use of $\Delta A_{t,i}$ in production, using his past technology instead.[13] An example of a technology that did not generate the expected results, and in many respects was judged as inferior to its

[12] In reality, firms can invest their profits, among other things, in capital stock, consumption and dividends to shareholders. However, since in this model no production function is specified and there is lack of shareholders and consumption, I am making the assumption that all past period's profits are used in innovating.

[13] Alternatively, in order to avoid $\Delta A_{t,i}$ having a negative value, one can assume that υ_i is lognormally distributed.

predecessor, would be High Definition TV (HDTV). In the late 1980's this was a promising European TV standard that turned out to be far more costly and outdated (when compared to the USA TV technology of its time).[14]

As I mentioned in section 2.1, each innovator aims at reaching some set "goals/targets". These goals can be considered as the expectation of the society as to what it wants future technology to be. These goals can be set by either a governmental body or by a central planner (who acts for the benefit of the society). An example of such a target set by the society (central planner) is the goal to create medication for AIDS. An example for a government set target would be the standards set in defence contracts. In both cases, innovators try to create innovations that can reach these targets.[15] Henceforth, I will use the general term "social target" in order to describe these "goals/targets".

I will make the assumption that the expectation for future technology that society has (the "social target"), will depend positively on how innovative (in its capacity to produce innovations that have a greater ΔA) this technological sector has been (the MP3 industry in this case). This line of thinking suggests that, when dealing with a very innovative technological sector, society will have greater expectations for this technology, in comparison to the technology created by a less innovative technological sector.[16]

An intuitive example of such a "social target" is, $\Delta\phi_t = \alpha\left(\int_0^n \frac{\Delta A_{t-1,i}}{\zeta_{t-1}} dj\right)$, $\alpha > 1$. This equation, expresses the "social target" $\Delta\phi_t$ as a function of the average innovation created by all innovators $\zeta \in [0,1]$, $\zeta \leq n$, who managed to innovate at time $t-1$. In this setting, the

[14] In 1991 the European Commission, in an initiative that was backed up by various satellite interests, proposed an expensive plan, which was worth of 850 million Euro, to support the HDTV standard plan. There was considerable debate in the Council about the budget, but finally the issue was dropped, with the justification being that a more advanced technology was already available in the US. For a detailed discussion of the HDTV project see Braithwaite and Drahos (2000).

[15] For a similar assumption see Scott (1996, 1997).

[16] Taking the above argument into extremes, suggest that Say's law is at work here, since the supply of innovations will determine the expectations of the society as regards to what it wants the new technology to be. Schmookler (1966), in his survey of the innovations produced by the railway industry, notes evidence of this.

greater the average innovation $\left(\int_0^n \frac{\Delta A_{t-1,i}}{\zeta_{t-1}} dj\right)$ is, the greater $\Delta\phi_t$ will be. In addition, a higher α indicates a technology for which $\Delta\phi_t$ moves faster. Allowing different technologies to have a different α, one can discriminate between technologies for which $\Delta\phi_t$ moves faster compared to others. Returning to the paradigm offered in the previous section, a greater α allows one to model the central planner's goal for the MP3 technology (a new-technology) as faster moving compared to that of the steam engine technology (a "mature" technology).[17] In this context, $\Delta\phi_t$ is an indicator of how useful this technology is to society. In contrast to $\Delta\phi_t$, ΔA is a quantitative index which expresses the magnitude of the technology, when compared to its initial starting point A_0.

Each innovator will be endowed with a probability of reaching the "social target". This probability will be exogenous[18] and it will be a function of the innovator's ability to innovate $p(\upsilon_i) \in [0,\ 1]$, where $Ep(\upsilon_i) \neq 0$[19] and $\frac{\partial p(\upsilon_i)}{\partial \upsilon_i} > 0$, $\frac{\partial^2 p(\upsilon_i)}{\partial \upsilon_i^2} < 0$. In this context, $p(\upsilon_i)$ (for simplicity p_i) describes by how far the innovator will advance, compared to the "social target". If $p_i = 1$, then he will manage to create an innovation that is equal to the full magnitude of $\Delta\phi_t$, if p_i is less than one then his innovation will be $p_i\Delta\phi_t$. Hence, each innovator i is expected to generate an innovation of magnitude $Ep_i\Delta\phi_t$. It should be noted that, if an innovator creates an innovation that is greater than the "social target" $\Delta\phi_t$, then only he will be able to fully appreciate his innovation. All the other innovators have a limited foresight, hence they will not be able to comprehend the innovation's full magnitude. In this case, the innovator will have created some tacit knowledge, in the form of an additional increment, that can only be used by him and it will not spillover to others.

In this framework, the "social target" $\Delta\phi_t$, introduces a multidimensional tournament effect, that allows one to discriminate among otherwise homogeneous agents. Hence, each innovator

[17] The steam technology, as David (1990) notes, was the main technology driving production until early in the 20th century.

[18] Scott (1996, 1997) allows firms investing in R&D to generate innovations that aim for the social target, but instead of assuming the probability of success as exogenous, it is an endogenous function of the firm's R&D.

[19] E is the expectation operator.

competes not with others, but with an endogenous goal $\Delta\phi_t$. How well the innovator performs in such a race, depends on his ability to innovate υ_i. Thereby, $p(\upsilon_i)$ displays how good the innovator's technology is. In other words, $p(\upsilon_i)$ is a weight indicating to the rest of the innovators how useful the innovator's technology is and how much of it should they use; i.e. $p(\upsilon_i)\Delta\phi_t$.

Assuming for simplicity that $n = 1$, the average spillovers that each innovator attains are equal to,

$$s_t = \zeta_t \Delta\phi_t \int_0^1 p_i dj \tag{2}$$

where ζ_t is the percentage of innovator's who actually innovate.[20] For simplicity equation (2) can be expressed as,

$$s_t = \zeta_t \Delta\phi_t \delta \tag{3}$$

where $\delta = \int_0^1 p_i dj$. Substituting this equation into the "technology generating" function, one can derive the expected innovation created by innovator i as,

$$E\Delta A_{t,i} = \zeta_{t-1}\pi_{t-1,i}\Delta\phi_{t-1}E\delta \tag{4}$$

3 Demand

This section will concentrate on describing the demand for a good that is produced using a specific technology in a frictionless Walrasian market of size M. In this economy, at time t, each innovator i, $i \in [0, 1]$ will produce one innovation $\Delta A_{t,i}$, which will be used in the production of one good. The good produced through the use of innovation $\Delta A_{t,i}$, will be consumed by a homogeneous mass of consumers who are infinitely lived, have identical additive preferences, defined over lifetime consumption and a constant rate of time preference r. Goods are substitutes, and innovations are assumed to be non-drastic. As a result, there is demand for all innovations. Specifically, the demand $Q_{t,i}$ for a good i, that has been manufactured through

[20] Since $n = 1$, ζ_t equals the number of innovators who innovate as well.

the use of the innovation made by the i innovator at time t, is given by the following expression,

$$Q_{t,i} = M \frac{\Delta A_{t,i}}{\int_0^1 \Delta A_{t,j} dj} \ , \ \Delta A_{t,i} \in (0 \ , \ \infty) \tag{5}$$

Equation (5), explains the demand for the good produced using the technology $A_{t,i}$ only as a function of the latest innovation $\Delta A_{t,i}$. Thus, consumers are interested in vintage technologies. Evidently, the demand for the good employing the $\Delta A_{t,i}$ innovation will depend positively on $\Delta A_{t,i}$, and negatively on the collective magnitude of the innovations created by the rest of the innovators, i.e. $\int_0^1 \Delta A_{t,j} dj$.[21] Furthermore, equation (5), implies that the total demand for all goods will be equal to M. Equally, if there is only one innovator i, $Q_{t,i}$ will also be equal to M.

4 The innovator's profits

In this framework, when an innovator creates an innovation he immediately patents his innovation and licences it to competitors for a royalty that is equal to the size of the innovation that they will be employing in their research. This being the case, if innovator i chooses to use $p_j \Delta\phi_t$ of the research that is carried out by innovator j, then he must pay him $p_j \Delta\phi_t$ in property rights. However, how much of $p_j \Delta\phi_t$ innovator i will make use of, will depend on the patent breadth z_t^2, where $0 < z_t^2 < 1$. In what follows, I will assume that patent breadth is a choice variable for the innovator. In reality, patent breadth is set out by the patent office (and the courts). However, it is up to the innovator to seek litigation if he feels that someone has been freely using his technology. Thus, the amount of technology transfer that takes place is up to the innovator's discretion. Accordingly, what I am modeling as a choice variable is not patent breadth *per se*, but technology transfer. For this reason, I will use the generic term IP protection in order to describe how much of his technology the innovator decides to freely share.

Assumption 1: *The choice of z_t^2 applied by innovator i on his innovation, when licencing it to innovator j, will be the same to the one that innovator j chooses.*

[21] For a similar assumption see Scott (1997).

This assumption implies that there exists some form of reciprocality among innovators. Hence, if innovator i licences his innovation to innovator j applying a z_t^2 degree of IP protection, innovator j will reciprocate using a z_t^2 degree of IP protection towards innovator i.[22]

Following assumption 1, innovator i will apply a z_t^2 degree of IP protection to his innovation. Thus, innovator i will receive $z_t^2 p_i \Delta\phi_t$ in royalties by each innovator who uses his innovation, and at the same time he has to pay property rights that are equal to $z_t^2 p_j \Delta\phi_t$ to each innovator j whose innovation he makes use of. Assuming that ζ_t percent of innovators will choose to innovate, the average property rights that innovator i has to pay to the other innovators are equal to,

$$z_t^2 \zeta_t \Delta\phi_t \delta$$

in addition, innovator i will receive

$$z_t^2 \zeta_t p_i \Delta\phi_t$$

in property rights. In all, each innovator will derive some income, because his innovation ΔA_i is used in the production of the good i, moreover, he will benefit from the royalties that he receives from the other innovators who make use of his technology. However, he also has to pay some royalties in order to benefit from the research of others. Accordingly, the innovator's average

[22] Bessen (2002), and Shapiro (2001), have shown that many major firms have created patent thickets (patent portfolios) which they can use (if they chose to) to block, not just similar innovations, but also innovations that may follow alternative techniques. In reality, most firms seldom use their patent portfolios in order to block innovation, Teece (2000). Nevertheless, such patent thickets act as deterrents to any firm which may act as a challenger. This analysis seems to suggest that there exist principal agents who have the means and power to enforce their will. Thus, less prominent firms have no choice but to follow on the footsteps of the major ones.

Thereby, if the major patent portfolio holders choose to litigate a lot, the other firms are left with no other choice but to go to court. Similarly, if the major patent portfolio holders choose to avoid litigation, it is not to the interest of less prominent firms to litigate against them (for if they choose to go to court larger firms have two advantages: a greater patent portfolio, and more money, thus they should be the most likely to win any court case against them). In the light of the above, assumption 1 is not unrealistic.

gross income will be equal to,[23]

$$I_{t,i} = Q_{t,i} + \zeta_t z_t^2 p_i \Delta\phi_t - \zeta_t z_t^2 \Delta\phi_t \delta \tag{6}$$

However, as Segerstrom (1998) notes, as the technology level increases it becomes harder to innovate. This is because starting technologies are easier to comprehend, while the more they develop they increasingly need more and more expertise. Thereby, the innovator has to pay a cost c for innovating, a cost that must be proportional to the innovation. Accounting for such a cost implies that technological growth will not follow an explosive path, allowing for a steady state solution. In what follows, I will model such a "technology development cost" as, $\frac{c\Delta A_{t,i}}{s_t}$. Using a formula as such implies that, the greater the degree of spillovers s_t that the innovator can attain (through the use of the work carried out by others) the less the innovation cost that he has to incur. In other words, the more the people working on one field, the easier it is for one to innovate. Including such a "technology development cost" in equation (6), equation (6) becomes,

$$I_{t,i} = Q_{t,i} + \zeta_t z_t^2 p_i \Delta\phi_t - \zeta_t z_t^2 \Delta\phi_t \delta - \frac{c\Delta A_{t,i}}{s_t} \tag{7}$$

where I assume that $M > 1$ and $c < 1$, so as for $Q_{t,i} > \frac{c\Delta A_{t,i}}{s_t}$, implying that the complexity of an innovation cannot be large enough to hinder innovation.

Assuming that innovations are distributed Normally, only a few innovators will actually have a Q that is high enough to guarantee them a high income. Keeping in mind that p_i is also Normally distributed, this line of thinking implies that the amount of royalties payed to the innovator, i.e. $\zeta_t z_t^2 p_i \Delta\phi_t$, will be limited for the majority of the innovators. Consequently, some innovators will be adversely effected by the royalties that they have to pay, since their average gross income $I_{t,i}$ will not be greater than zero. This implies that an increase in the degree of IP protection z^2 would decrease the number of innovators who find it profitable to innovate; the ones whose average gross income $I_{t,i}$ is greater than zero.

[23] In both the property rights that the innovator receives, as well as the royalties that he has to pay, I have not included the innovator's own contribution $p_i\Delta\phi$, because they cancel out.

Proposition 1 There is negative relationship between the number of innovators who find it profitable to innovate and the degree of IP protection.

Proof. innovator i will find it optimal to innovate only if his gross income $I_{t,i}$ is greater than zero. This suggests that the following inequality must hold,

$$Q_{t,i} - \frac{c\Delta A_{t,i}}{s_t} > \zeta_t z_t^2 \Delta\phi_t \left(\delta - p_i\right)$$

Since I have assumed that $Q_{t,i} > \frac{c\Delta A_{t,i}}{s_t}$, and δ is greater than p for the majority of the innovators (assuming that innovations are distributed Normally), both sides of the above inequality are positive. Thus, increases in z_t^2 imply that, for some innovators, the above inequality will not hold. Moreover, further increases in z_t^2 will affect a greater number of innovators. ■

This finding seems realistic, if one accounts for the increased litigation that accompanies broadening patent protection.[24] Furthermore, this proposition accords with the evidence offered by Lerner (1995), who finds that in the biotechnology industry, when firms are faced with a strong patent barrier, they choose to redirect their innovating effort to projects where the patents that competitors have will not pose as many problems. Indirect evidence for this negative relationship is provided by Aghion et al. (2002). Specifically, measuring innovative activity through the use of a weighted patent index, they find that a non-linear (inverted U) relationship exists between innovation and market competition.[25] [26] [27]

For mathematical convenience, I will assume that the number of innovators who find it

[24] Galini (2001) reports that starting firms must be ready to spend 2-3 million $ in litigation, if they want to either use other people's patents, or protect their own. In addition, as Lanjouw and Schankerman (2001) note, "for the most valuable drugs and health patents the estimated probability of litigation during the lifetime of the patent is more than 25%, and more than 10% in other technology fields. As a percentage of utilized patents, these litigation rates would be even higher".

[25] Hence, after a point, fierce competition reduces the number of patents.

[26] To this finding, one should add the evidence offered by Panagopoulos (2002), who finds a similar, non linear, relationship with respect to growth.

[27] If one controls for firm effects by using bellow-firm-level data on R&D activity the inverted U relationship disappears, Scott (1993).

profitable to innovate is equal to ϵz_t^{-1} where $\epsilon \in (0,1)$.[28] Subsequently, if one substitutes equation (3) in equation (7), and replaces ϵz_t^{-1} in place of ζ_t, the innovator's average income will become,

$$I_{t,i} = Q_{t,i} + \epsilon z_t p_i \Delta\phi_t - \epsilon z_t \Delta\phi_t \delta - \epsilon^{-1} z_t \frac{c\Delta A_{t,i}}{\Delta\phi_t \delta} \tag{8}$$

In this framework, following Jones (2001), the innovator will not appropriate all of the income that is created from producing output $Q_{t,i}$. He will appropriate only a share $z_t^2 Q_{t,i}$. Hence, the innovator's average profits at time t are,

$$\pi_{t,i} = z_t^2 Q_{t,i} + \epsilon z_t \Delta\phi_t (p_i - \delta) - \epsilon^{-1} z_t \frac{c\Delta A_{t,i}}{\Delta\phi_t \delta} \tag{9}$$

5 The innovator's maximization problem

Innovators maximize their profits subject to their "technology generating" function. Their choice variable is the degree of IP protection z^2, and their state variable is ΔA. The innovator's "technology generating" function is given by $\Delta A_{t,i} = s_{t-1}\pi_{t-1,i} + \upsilon_i$. Accounting though for equation (3), this equation becomes $\Delta A_{t,i} = \epsilon\zeta_{t-1}\Delta\phi_{t-1}\delta\pi_{t-1,i} + \upsilon_i$. However, $\zeta_{t-1} = \epsilon z_{t-1}^{-1}$, allowing one to express the innovator's "technology generating" function as,

$$\Delta A_{t,i} = \epsilon z_{t-1}^{-1} \Delta\phi_{t-1} \delta \pi_{t-1,i} + \upsilon_i \tag{10}$$

In all, the innovator's problem can be written down as,

$$\max_{z^2} \sum_{t=0}^{t} \beta^t \pi_{t,i} \quad \text{s.t} \quad \Delta A_{t,i} = \epsilon z_{t-1}^{-1} \Delta\phi_{t-1} \delta \pi_{t-1,i} + \upsilon_i$$

with initial condition $A_{0,t} = A_0 \to 0^+$. Accounting for equation (9), one can restate the innovator's expected maximization problem as,

$$\max E \sum_{t=0}^{t} \beta^t \left[z_t^2 Q_{t,i} + \epsilon z_t \Delta\phi_t (p_i - \delta) - \epsilon^{-1} z_t \frac{c\Delta A_{t,i}}{\Delta\phi_t \delta} \right] \text{ s.t. } E\Delta A_{t,i} = \epsilon z_{t-1}^{-1} \pi_{t-1,i} \Delta\phi_{t-1} E\delta$$

[28] The assumption that $\epsilon \in (0,1)$ is included so as to have $z^{-1} \in (0,1]$.

Suppressing, henceforth, the expectations operator E and allowing M to be a large number, the steady state FOC can be expressed as,

$$\widetilde{z} \sim \left(\frac{1+c}{\epsilon \delta \Delta \widetilde{\phi} M} \int_0^1 \Delta \widetilde{A}_j dj \right) \tag{11}$$

where $\Delta\widetilde{\phi}$ is the steady state "social target", and $\Delta\widetilde{A}_i$ is the steady state innovation of innovator i. From the steady state solution, it is clear that increases in the size of the steady state "social target", or in the size of the market, will cause a downward shift in $\widetilde{z}$. Contrary to that, increases in the size of the market which the other innovators occupy (i.e. $\int_0^1 \Delta\widetilde{A}_j dj$), will cause an increase in $\widetilde{z}$. The above discussion implies that markets where the technology progresses quickly[29] (i.e. the $\Delta\widetilde{\phi}$ is big) should allow for a small degree of IP protection.[30] This finding accords with Gort and Klepper's study of technology product life cycles. Specifically, they find that most of the firm's patenting takes place in the latter stage of its research and not during its early stages.[31]

6 When should RJVs be formed

In this section I will concentrate on deriving the conditions under which an RJV will be formed. I will work under the assumption that an RJV is a partnership between an innovator (a private firm) and a university. The objective of the potential partners would be to benefit from the technological expertise that the other partner has, or alternatively to benefit from the profits that the other partner has.

In this model all innovators start from a very low starting point $A_0 \to 0^+$, without any external finance. These innovators progressively develop their technology A_i by creating innovations ΔA_i, which they profit from. Hence, *ceteris paribus* the magnitude of ΔA_i, when compared to the one that the other innovators create, depends on the innovator's ability υ_i, see equation

[29] The capacity of the model to allow the innovator to choose a low degree of IP protection when dealing with a fundamental technology, accords with the historical evidence offered by Rosenberg (1994), Mowery and Rosenberg (1989), and Nelson (1962), with respect to the invention of the transistor.

[30] For a detailed discussion of the effects of δ and $\int_0^1 \Delta A_j dj$ on the above equation see Panagopoulos (2003).

[31] Gort and Klepper, (1982).

(1). Accordingly, the main factor determining how well an innovator preforms, and how big his profits are, is υ_i. This intuition suggests that, if one of the potential partners is lacking capital and wants to benefit from the profits of the other partner, in developing some technology, then there must be a mismatch in the individual ability of each potential partner to innovate. Considering that it is irrational for a good innovator to jointly do research with a bad one, I will henceforth concentrate on the first objective -i.e. innovators and firms want to form an RJV to simultaneously benefit from the expertise that each other has.

In this context, the average profits of an innovator i, who has created, at time t, some innovation $\Delta A_{t,i}$, are given by equation (9). These profits include the gains that the innovator makes from his innovation $z_{t,i}^2 Q_{t,i}$, as well as the cost $\epsilon z_{t,i} \Delta\phi_{t,i} (\delta - p_i) + \epsilon^{-1} z_{t,i} \frac{c\Delta A_{t,i}}{\Delta\phi_{t,i}\delta}$, where $z_{t,i}^2$ is the degree of IP protection that the innovator would choose and $\Delta\phi_{t,i}$ depicts how fast $A_{t,i}$ is evolving. If an innovator forms an RJV with a university, the two partners must decide on how to split the gains and the cost. Assuming that they decide upon a simple form of contact, one that attributes to each partner a set percentage η_1 of the gains and η_2 of the cost, their contract should be given by the following set, (η_1, η_2), where $\eta_{1,2} \in [0, 1]$. This being the case, the average profits $\pi_{t,i}$ of the innovator must be the following,

$$\pi_{t,i} = \eta_1 z_{t,R}^2 Q_{t,R} - \eta_2 z_{t,R} \left[\epsilon \Delta\phi_{t,R} (\delta - p_i) + \frac{\epsilon^{-1} c \Delta A_{t,R}}{\Delta\phi_{t,R}\delta} \right]$$

where $\Delta A_{t,R}$ is the expected innovation that the RJV will create, $Q_{t,R}$ is the demand for the good produced using $\Delta A_{t,R}$, $z_{t,R}^2$ expresses the degree of IP protection that the RJV will choose, while $\Delta\phi_{t,R}$ expresses how fast $A_{t,R}$ is evolving.

However, to the above profits one must include the opportunity cost of the innovator. The opportunity cost of the innovator will be the profits that he would forego, if he chooses to stop working on his own technology $A_{t,i}$ and starts working on the technology that the RJV will develop.[32] This opportunity cost must be equal to,

$$z_{t,i}^2 Q_{t,i} - \epsilon z_{t,i} \Delta\phi_{t,i} (\delta - p_i) - \epsilon^{-1} z_{t,i} \frac{c\Delta A_{t,i}}{\Delta\phi_{t,i}\delta}$$

Accounting for the above opportunity cost, the overall average profits of innovator i are given by,

$$\begin{aligned} \pi_{t,i} &= \eta_1 z_{t,R}^2 Q_{t,R} - \eta_2 z_{t,R} \left[\epsilon \Delta\phi_{t,R} (\delta - p_i) + \frac{\epsilon^{-1} c\Delta A_{t,R}}{\Delta\phi_{t,R}\delta} \right] \\ &\quad - z_{t,i}^2 Q_{t,i} + z_{t,i} \left[\epsilon \Delta\phi_{t,i} (\delta - p_i) + \epsilon^{-1} \frac{c\Delta A_{t,i}}{\Delta\phi_{t,i}\delta} \right] \end{aligned} \quad (12)$$

Based on the above discussion and on equation (12), it is straight forward to derive a similar expression for the overall average profits of the university as well.

As expected, the above equation implies that the innovator (university) will base his decision, on whether to join an RJV, on the expected innovation $\Delta A_{t,R}$ that the RJV will create, as well as on the way that the partners will allocate both cost and gains i.e. (η_1, η_2). However, I have shown in the above section, that $z_{t,R}^2$ is case specific, and that it depends on how fast the technology evolves i.e. $\Delta\phi$. Thus, the innovator must also account for his choice of IP protection. Bearing the above in mind, one can show that the decision of the innovator and the university to form an RJV does not depend on the degree of the collective magnitude of innovations $\int_0^1 \Delta A_j dj$, nor on the size of the market M, but on $\Delta\phi$ (how fast technology is evolving).

Specifically, as the following proposition states, firms and universities that work on new technologies should find it easier to form an RJV. This result is derived under the assumption that universities are not different from firms, both in the way that they maximize profits, as well as in their research specialization; since they specialize in both new and "mature" technologies. If one is to make the more realistic assumption that universities specialize only on new technologies, then this result is reinforced.

Proposition 2 Universities and firms find it easier to form RJVs that specialize on new technologies.

[32] I assume that the innovator will stop his research on $A_{t,i}$ in order to avoid duplication. However, this assumption does not imply that he will choose to stop his entire research on this technology.

Proof. See Appendix 1. ■

This proposition accords with the evidence offered by Hall, Link and Scott (2000, 2001), who note that "universities are most likely to partner in new technological fields where R&D is closer to science",[33] as well as Link and Vonortas (2002), who list the RJVs between EU firms and US universities. In detail, the data of Link and Vonortas, included in figure 2, shows that most RJVs take place in technical areas that one would consider as fast evolving science, such as telecommunications. In reality, it is difficult to find which technical areas/industries can be considered as fast evolving science. One possible way is to find which industries are the most R&D intensive. Specifically, using the ISDB dataset,[34] the most R&D intensive industries are (intensity is defined as R&D spending per worker and is included in parenthesis next to the industry): transportation (1), computers (2), and telecommunications (3). Another possible way is to find which industries are the most patent intensive (patent intensity is used to express the number of patents that are granted per year and it is listed in parenthesis next to the industry). In this case, using the US statistical abstract one can find that telecommunications/electronics (1), transportation (2) and chemicals (3) are the most patent intensive industries. From the above, even though there is no doubt that my analysis just touches on this very interesting issue, a pattern emerges which suggest that telecommunications, computers, transportation and chemicals can be considered as technical areas/industries that use fast evolving science. All these industries (along with energy/environmental technologies[35]) are in the top of figure 2, having the majority of RJVs between EU firms and US universities.

[33] The reason that the authors offer is that universities offer research awareness, i.e. a research insight that is anticipatory of future research problems and could be an obudsman anticipating and translating to all the complex nature of the research being undertaken.

[34] This is an OECD data set that records, among other things, R&D expenditures per 3 digit industry; which means that it does not fully cover all the technical areas listed in figure 2.

[35] The ISDB data set has no records on the R&D spending of the energy and environmental industries. This is because of the ISIC code listing that ISDB uses which includes the above two industries in other industry listings. There is a similar problem with the data included in the US statistical abstracts.

In conclusion, such a line of approach indicates that firms which face a lower opportunity cost are the ones most likely to form an RJV. Hence, large firms (ones operating many different projects at the same time, some of which should be on new-technologies) and firms with financial resources (who don't care about the opportunity cost that much), would be the most likely candidates for such projects. The evidence offered by Caloghirou, Vonortas and Tsakanikas (2000), pointing to the fact that firms that sell by average over 1 billion Euros tend to cooperate much more with universities than firms who sell less, seems to offer support for the view expressed above.

7 Conclusion

In order to regenerate the country's R&D activity, which it was feared to be lagging behind that of Japan, the US Congress passed the Bayh-Dole Act allowing universities to patent their innovations more easily than before. However, the increase in RJVs between firms and universities, initiated by the Bayh-Dole Act, is not as significant as expected. This paper studies the reasons why firms and universities find it difficult to form RJVs, stressing the role of IP protection.

In its decision to form an RJV or not, a firm (and a university) has to make a choice between continuing to work along its own line of research, or to jointly develop a technology with a university. The choice of the firm will depend on how big its opportunity cost will be. As the paper shows, firms which already do research on new-technologies (i.e. technologies that are closer to science and are not yet "mature" and well-developed), have a lower opportunity cost, hence they are the most likely participants of such RJVs.

The explanation of the paper is premised on the importance of IP protection. Specifically, as firms (and universities) choose their preferential degree of IP protection in a market where firms licence their innovations to competitors, IP protection proves to be case specific. In particular, the degree of IP protection chosen by the firm will depend on how fast the technology evolves. In this framework, if the technology is new (fast evolving and closer to science), the firm will choose to share it, choosing to have a low degree of IP protection. Hence, the profits of the firm will be lower than those of a firm developing a slow moving, but "mature", technology. The intuition behind the firm's choice rests on the increased knowledge spillovers from which the firm will gain, if it chooses a low degree of IP protection on a technology that is not yet well-developed to create "quality" goods. Thereby, the opportunity cost for a firm that specializes on "mature" and well-understood technologies will be greater than the one of a firm specializing on new-technologies.

Essential to the above argument is the assumption that firms make similar choices regarding their preferred degree of IP protection. In addition, I have allowed innovation to be partly driven by an exogenous parameter whose aim is to represent ability. These simplifications have greatly aided in simplifying the model but leave room for further research, hopefully in a model in which IP protection will be non-cooperative.

8 Appendix 1

Proof. In this proof I will concentrate on finding the profits of the innovator (a private firm) and the university, when joining an RJV. Since, by joining the RJV the innovator (university) enters into a contract which specifies how the cost and the profits are split, I will concentrate this proof on the best case scenario for the innovator and the university, and afterwards offer a proof for the more general case. Initially, I will concentrate on the innovator and then on the university.

The most preferable outcome for the innovator is the one where the innovator appropriates all the gains, while the university all the cost. Symmetrically, the worst case scenario is the one where the innovator appropriates all the cost, making negative profits; and thus decides to abstain from any RJV. Specifically, equation (12) shows that in order for a innovator to find it profitable to participate in an RJV, the following inequality must apply,

$$\begin{aligned} &\eta_1 z_{t,R}^2 Q_{t,R} - \eta_2 z_{t,R}\left[\epsilon\Delta\phi_{t,R}\left(\delta - p_i\right) + \frac{\epsilon^{-1} c\Delta A_{t,R}}{\Delta\phi_{t,R}\delta}\right] \\ > \; & z_{t,i}^2 Q_{t,i} - z_{t,i}\left[\epsilon\Delta\phi_{t,i}\left(\delta - p_i\right) + \epsilon^{-1}\frac{c\Delta A_{t,i}}{\Delta\phi_{t,i}\delta}\right] \end{aligned} \tag{13}$$

Allowing the economy to be on a steady state, and substituting equations (11), (5), in the above inequality, one can re-express equation (13) as,

$$\begin{aligned} &\eta_1\left(\frac{1+c}{\epsilon\delta\Delta\widetilde{\phi}_R M}\int_0^1 \Delta\widetilde{A}_j dj\right)^2 \frac{M\Delta\widetilde{A}_R}{\int_0^1 \Delta\widetilde{A}_j dj} \\ &-\eta_2\left(\frac{1+c}{\epsilon\delta\Delta\widetilde{\phi}_R M}\int_0^1 \Delta\widetilde{A}_j dj\right)\left[\epsilon\Delta\widetilde{\phi}_R\left(\delta - p_i\right) + \epsilon^{-1}\frac{c\Delta\widetilde{A}_R}{\Delta\widetilde{\phi}_R\delta}\right] \\ > \; &\left(\frac{1+c}{\epsilon\delta\Delta\widetilde{\phi}_i M}\int_0^1 \Delta\widetilde{A}_j dj\right)^2 \frac{M\Delta\widetilde{A}_i}{\int_0^1 \Delta\widetilde{A}_j dj} \\ &-\left(\frac{1+c}{\epsilon\delta\Delta\widetilde{\phi}_i M}\int_0^1 \Delta\widetilde{A}_j dj\right)\left[\epsilon\Delta\widetilde{\phi}_i\left(\delta - p_i\right) + \epsilon^{-1}\frac{c\Delta\widetilde{A}_i}{\Delta\widetilde{\phi}_i\delta}\right]. \end{aligned} \tag{14}$$

Allowing for $\Delta\widetilde{A}_R = \Delta\widetilde{A}_i$ implying that the innovator will not suffer from a decrease in demand if he forms an RJV, the most profitable scenario for the innovator is the one where $\eta_1 = 1$, and $\eta_2 = 0$. This means that, by joining the RJV, the innovator gets all the gains from this new technology, without incurring any of the cost. If this scenario is true than the above inequality can be expressed as,

$$\begin{aligned} &\left(\frac{1+c}{\epsilon\delta\Delta\widetilde{\phi}_R M}\int_0^1 \Delta\widetilde{A}_j dj\right)^2 \frac{M\Delta\widetilde{A}_R}{\int_0^1 \Delta\widetilde{A}_j dj} \\ > \; &\left(\frac{1+c}{\epsilon\delta\Delta\widetilde{\phi}_i M}\int_0^1 \Delta\widetilde{A}_j dj\right)^2 \frac{M\Delta\widetilde{A}_i}{\int_0^1 \Delta\widetilde{A}_j dj} \\ &-\left(\frac{1+c}{\epsilon\delta\Delta\widetilde{\phi}_i M}\int_0^1 \Delta\widetilde{A}_j dj\right)\left[\epsilon\Delta\widetilde{\phi}_i\left(\delta - p_i\right) + \epsilon^{-1}\frac{c\Delta\widetilde{A}_i}{\Delta\widetilde{\phi}_i\delta}\right] \end{aligned}$$

Canceling out equal terms and rearranging, it is straight forward to derive the following inequality,

$$\frac{1}{c+1}\left(\frac{\epsilon^2\Delta\widetilde{\phi}_i\delta\left(\delta-p_i\right)}{\Delta\widetilde{A}_i}+1\right)>\left(\frac{\Delta\widetilde{\phi}_R-\Delta\widetilde{\phi}_i}{\Delta\widetilde{\phi}_R}\right) \tag{15}$$

Apparently, the right hand side of equation (15) displays the percentage difference between $\Delta\widetilde{\phi}_R$ and $\Delta\widetilde{\phi}_i$. If this difference is either zero, or negative, this inequality will always apply. Subsequently, equation (15) shows that the innovator's decision does not depend on the degree of market concentration $\int_0^1 \Delta A_j dj$, nor on the size of the market M. It only depends on

$$\left(\frac{\Delta\widetilde{\phi}_R-\Delta\widetilde{\phi}_i}{\Delta\widetilde{\phi}_R}\right)$$

i.e. how fast does the RJV's technology evolves, compared to the technology that the innovator is working on. This inequality will always be satisfied if $\Delta\widetilde{\phi}_i \geq \Delta\widetilde{\phi}_R$.

Cancelling out the assumption of the best case scenario, where $\eta_1 = 1$ and $\eta_2 = 0$, allowing though for symmetry $\Delta\widetilde{A}_R = \Delta\widetilde{A}_i$, the inequality included in equation (14) becomes,

$$\frac{\epsilon^2\delta\left(\delta-p_i\right)(1-\eta_2)\Delta\widetilde{\phi}_R^2}{\Delta\widetilde{A}_i}+(1+c)\eta_1>\frac{\Delta\widetilde{A}_i}{\delta^2}\left(\frac{\Delta\widetilde{\phi}_R^2-\eta_2 c\Delta\widetilde{\phi}_i^2}{\Delta\widetilde{\phi}_i^2}\right) \tag{16}$$

In order for this inequality to always hold the following must be true, $\eta_2 c\Delta\widetilde{\phi}_i^2 > \Delta\widetilde{\phi}_R^2$. Bearing in mind that $(\eta_2,\ c) < 1$, this expression suggests that $\Delta\widetilde{\phi}_i$ must be much greater than $\Delta\widetilde{\phi}_R$. This implies that an innovator will always find it profitable to form an RJV if he is working on a new technology.

Up to now I have concentrated on what determines the decision of the firm. Accordingly, I have excluded universities from the decision process. In what follows, I will apply the rationale developed above in order to find what factors determine the university's decision to join an RJV. In a manner similar to the above proof, I will allow a university to have an opportunity cost. Forming the university's problem in a fashion similar to equation (14), it is easy to derive that in the steady the following inequality must apply,

$$\frac{\epsilon^2\delta\left(\delta-p_u\right)(1-\eta_2)\Delta\widetilde{\phi}_R^2}{\Delta\widetilde{A}_u}+(1+c)\eta_1>\frac{\Delta\widetilde{A}_u}{\delta^2}\left(\frac{\Delta\widetilde{\phi}_R^2-\eta_2 c\Delta\widetilde{\phi}_u^2}{\Delta\widetilde{\phi}_u^2}\right) \tag{17}$$

where the subscript u, indicating a university, has taken the place of the subscript i, which indicated the innovator. Similarly, for this inequality to always hold the following must be true, $\eta_2 c \Delta \widetilde{\phi}_u^2 > \Delta \widetilde{\phi}_R^2$. Thereby, a university will always find it profitable to form an RJV if it is working on a new technology.

In conclusion, innovators that work on new technologies should find it easier to fulfill equation (16) and form an RJV with a university, in addition the same is true for universities. This line of thinking suggests that there is only one Nash equilibrium. In this equilibrium the two partners will cooperate only if they are both working on a new technology.

If one is to assume that universities specialize on new technologies, see Beath et all (2001) for a similar assumption, then the above proposition will still apply. This is because universities, since they already work on new technologies, have a low opportunity cost. Using equation (17), It is straight forward to show that a low opportunity cost as such will make universities eager to participate in an RJV that concentrates on both new and "mature" technologies. This is because the right hand side of equation (17) is always negative, thus the inequality expressed through equation (17) always holds. On the other hand, as I have already explained, only innovators that incur a low opportunity cost will choose to join an RJV, and these innovators are ones that work on new technologies. Thus, if an RJV is to be formed, it will specialize on new technologies. ■

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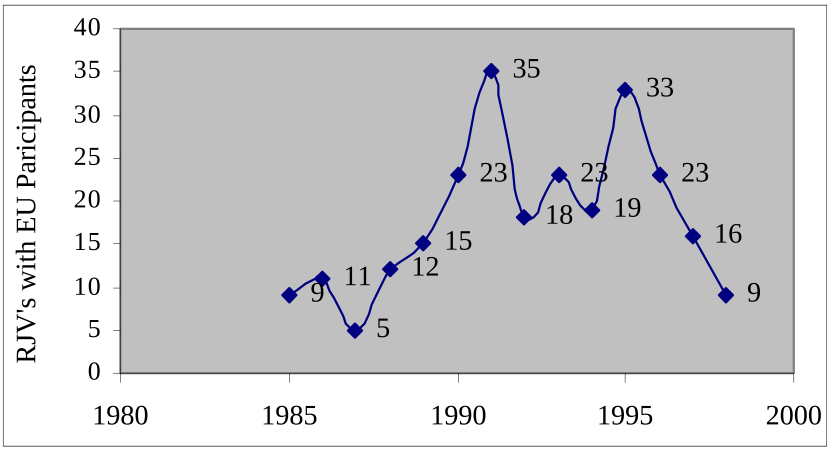

Figure 1: RJVs between EU firms and US universities. Source, Link and Vonortas (2002).

Technical Area	Total RJVs 1985-1998	%
Telecommunications	40	15,94
Energy	32	12,75
Environmental	32	12,75
Computer Software	27	10,76
Chemicals	26	10,36
Transportation	20	7,97
Advanced Materials	19	7,57
Subassemblies & Components	14	5,58
Factory Automation	10	3,98
Test & Measurement	6	2,39
Biotechnology	5	1,99
Computer Hardware	4	1,59
Manufacturing Equipment	4	1,59
Photonics	4	1,59
Medicals	3	1,20
N/A	3	1,20
Pharmaceuticals	2	0,80
Total RJVs	251	100

Figure 2: This figure includes the number of RJVs between EU firms and US universities, Link and Vonortas (2002).