Competition, Innovation and Research Joint Ventures*

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**Competition, Innovation and Research Joint Ventures**

In this paper I will review the work undertaken within our TSER project on Competition, Innovation and Research Joint Ventures (RJVs).

There are a number of inter-related issues lying behind the work done in this area.

The first is the link between innovation and competition, or between market structure and the outcome of R&D competition. This is a long-standing concern, with much discussion of the nature and direction of the connection between the two. Theoretical developments over the last ten to fifteen years have clarified the connections and given us a framework for thinking in which market structure and the nature of R&D competition are simultaneously and endogenously determined. Given the complex theoretical links, a careful microeconometric investigation of the link between market structure and R&D competition raises many difficulties. Work undertaken in this TSER project has made important developments in this direction, which I will survey later on.

There is an obvious link between innovation and research joint ventures (RJVs) in that RJVs are often seen as a way of overcoming some of the market failures in the innovation process. However since RJVs are collaborative agreements they would normally be outlawed under competition policy. A major policy of the EU has been the promotion of RJVs both through block exemptions to competition policy, and by R&D subsidies through various framework programmes. The presumption is that while RJVs collaborate on R&D they compete in the product market, and this is how they have typically been modelled in much of the theoretical literature.

However the earlier theoretical framework for thinking about RJVs has recently been challenged as not being fully adequate for understanding the link between RJVs, competition and innovation. Work undertaken in this TSER project has gone a long way towards providing a richer framework for evaluation.

Since this is the work in which I have been primarily involved, when I was asked to write the survey of the work done in our TSER project, I used the opportunity to stand back and reflect on what more than 10 years of research on RJVs has accomplished. It was somewhat disappointing, with a number of different models pointing in different directions, and some ideas which had been much discussed informally, but which were not fully captured in the theory. This lack of a proper framework was reflected in difficulties faced by scholars trying to evaluate RJVs and RJV policy.

In this paper I have therefore tried to develop a framework which tries to draw together many of the ideas in the literature on RJVs. I hope this framework might enable us to

(i) better understand the work undertaken in this TSER project and its connection to other literature;
(ii) identify the directions for further research;

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2 See for example Beath Katsoulacos and Ulph (1995) for a survey.
(iii) reflect on what conclusions might emerge for policy makers.

The plan of the paper is as follows. In section 1 I will set out a general overview of the market failure issues which RJVs might be thought to address, and the way they might do this. Section 2 develops a more formal model to capture these ideas. Section 3 then reviews the literature and the contribution of the work undertaken in this TSER project to that literature. Section 4 indicates directions for further research which emerge from this study, while Section 5 offers some conclusions.
Section 1  An Overview of Market Failures in Innovation and the Role of RJVs

It is well known there are significant potential market failures in the innovation process. These stem fundamentally from the appropriability problems that arise from the public good nature of knowledge. In the absence of any form of policy intervention these problems imply that the private rate of return to R&D would be extremely low, and consequently there would be considerable underinvestment in R&D. To address these problems most governments operate a system of protection of intellectual property rights (IPRs) – the central component of which is patent protection. However, while policy intervention in the form of a patent system provides some correction of the basic market failures, it generates its own distortions, essentially because patents reward firms for discovering information but not for sharing it.

To understand this point consider first a policy system in which
(i) there are no mechanisms for (voluntary) information sharing or research co-ordination among firms;
(ii) patents are completely effective and can prevent all involuntary information leakages or spillovers;

For the moment, suppose also that:
(iii) firms are producing substitute products – an assumption made in much of the literature on innovation, spillovers and RJVs;
(iv) the research paths which firms are pursuing are what Katsoulacos and Ulph (1998) call perfect substitutes. That is the research that all firms are doing effectively leads to the same discovery. This assumption too is widely made in the literature on innovation.

In the discussion that follows, and throughout the paper, I will focus on the case where firms are involved in process innovation. Then, as is well known from the Industrial Organisation literature\(^3\) there will be a number of distortions in the R&D market.

(a) Firms will not usually be able to appropriate the extra consumers’ surplus from their innovations. By not taking into account consumers’ surplus in their objective firms tend to under-value the returns to R&D, and so will under-invest in R&D. We refer to this as the under-valuation effect.

(b) If, as in the non-tournament\(^4\) model of Dasgupta and Stiglitz (1980), firms make their R&D decisions non-strategically\(^5\), then each firm will have an additional reason for under-investing in R&D. For they take account of the benefit of the

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\(^3\) See the collection of articles in the “Handbook of the Economics of Innovation and Technological Change” (1995).

\(^4\) For a discussion of the distinction between tournament and non-tournament models of R&D competition, see, for example, Beath, Katsoulacos & Ulph (1995).

\(^5\) That is firms choose output and R&D simultaneously rather than sequentially.
R&D to themselves, and so, given the substitute nature of the research, they ignore the potential benefit that the outcome of their R&D could bring to others -if the results of their R&D were shared. Call this the *non-strategic under-investment effect*.

(c) However, if firms choose R&D strategically then there is a factor leading each firm to over-invest in R&D - since each firm tries to gain at their rival’s expense. This overinvestment is most dramatic in the case of tournament (race) models, but also arises in non-tournament models where firms choose R&D prior to the output stage of the game. Call this the *strategic over-investment effect*.

(d) Finally there will be *excessive duplication* of R&D effort. If information were fully shared then fewer firms need undertake the R&D.

If we drop assumption (iv) and assume instead that firms pursue what Katsoulacos and Ulph (1998) refer to as complementary research paths, then there is no longer a concern under (d) about duplication of effort. Instead the concerns are as follows.

(e) Firm’s inability to co-ordinate their research will lead to the under-exploitation of the complementarities between their research. Notice that this co-ordination of research will typically require the exchange of information *prior* to undertaking R&D, so that firms can co-ordinate the direction of their research. Of course, a full exploitation will also require the exchange of information about research outcomes. This is in contrast to the concerns in (b) above which relate entirely to the exchange of information about the outcomes of R&D discoveries. Call this the *under-exploited complementarities effect*.

(f) Precisely because these complementarities are not fully exploited, firms will under-invest in R&D. Call this the *under-exploited complementarities under-investment effect*.

If we drop assumption (iii) and assume that firms are producing complementary products, then the above discussion gets modified in two ways. First it is much less likely that firms will be pursuing perfect substitute research paths – though this possibility is still allowed for in what follows. Second, since each firm now gains rather than loses when the costs of other firms are lowered, the magnitude of some of the above effects will be altered. For example, *ceteris paribus*, the strategic over-investment effect could be much smaller (and possibly even negative).

Consider now the implications of dropping assumption (ii) and allowing for the possibility of spillovers – defined as *involuntary, unpaid* leakages of information. In the case where firms produce substitute products and invest strategically in R&D, we have another consideration.
When firms are producing substitute products, then the larger the spillover, the smaller will be the amount of R&D undertaken by each firm. There are two reasons for this. If a firm succeeds in innovating when its competitors do not then it will have less to gain from its discovery since some of the information will leak out to others. However if a firm fails to innovate, while some of its rivals succeed, then it will gain from their discoveries, and so has less to lose from a failure to innovate. Both of these effects will imply that the larger the spillover the smaller the amount of R&D. Call this the spillover under-investment effect. Once again the discussion is somewhat modified when firms are producing complementary products, for now the first of the above effects is positive, since a firm gains from any progress made by the other firms.

So, in the absence of any mechanisms or policies for promoting information-sharing and/or R&D, we can see that patents – and IPR systems more generally – by no means resolve all the market failures associated with R&D. This is true even if the patent system works perfectly.

Three other conclusions emerge from the above discussion.

(I) Many of the failures arise because, under a patent system, firms are rewarded for creating information, but not necessarily for sharing it. Under our assumptions so far, whatever information passes from one firm to another does so involuntarily, and is unrewarded.

(II) There are two types of information that may need to be shared by firms. There is research design information that may need to be shared before any R&D is undertaken. This is necessary for firms to be able to co-ordinate research and exploit complementarities. It may also be necessary to avoid duplication of research effort. There is research outcome information that is shared after firms have made discoveries.

(III) The failures are quite complex – some point to under-investment, and some to over-investment.

Before turning to possible policies, let us consider a number of ways in which firms might voluntarily share information.

Firms would presumably be interested in voluntarily exchanging research design information and in co-ordinating research. However, such information is unlikely to be codified and so any exchange will have to take place through meetings etc. Clearly any research co-ordination will also required detailed meetings and planning. I take it that all of this is ruled out by competition policy. This does not mean that in the absence of explicit co-ordination there will be no compatibility of research design and so no

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6 Recent empirical work by Cassiman and Veuglers (1998) points up the difference between research output spillovers and research input spillovers.
possibilities of exploiting complementarities through information-sharing, but rather that such compatibility will be the haphazard outcome of independently taken decisions.

To the extent that it is codified, firms may still be able to exchange research output information. At the very least they could simply give this information away free of charge, and, as Katsoulacos and Ulph point out, would have incentives to do so if firms were producing complementary products.

However another way of sharing research output information is through licensing. The important point about licensing is that it now gives firms a direct financial reward for sharing information. This will raise the rate of return to R&D. However there a number of points make about licensing.

First, licensing would seem to work well when one firm has made a discovery of some new product/technology that is easily described, while another firm has not. It would seem less appropriate when two firms have both discovered and are trying to exploit complementarities through the mutual exchange of information about their discoveries.

Second, licensing is problematic when there are more than two firms, since the price any one firm is willing to pay to acquire a license will depend on how many other licenses are sold.

Third, even when there are only two firms involved, licensing will only take place when the maximum amount the buyer is willing to pay exceeds the minimum price the seller is willing to accept – and, as is well known, this condition will not always be satisfied. In particular, licensing may not occur when firms produce substitute products and the innovation is sufficiently large.

Finally, in the case where firms produce complementary products, and so would have been willing to give away their discovery free of charge, licensing may introduce a strategic incentive to invest that will lead firms to over-invest in R&D.

Against this background let us consider now the possible role for RJVs. First let me say what I mean by a research joint venture. A research joint venture (RJV) is a mechanism whereby firms are able to take decisions about all aspects of R&D in a collaborative/cooperative fashion.

In particular an RJV can act cooperatively on the following three sequences of decisions.

(1) Research Design and Co-ordination

This embraces two different decisions.
I.1 The number of laboratories to operate.

Here I assume that there are just two options. The RJV can either operate two independent laboratories – essentially one in each firm – or else it can operate a single laboratory staffed by scientists from each firm\(^7\). I take that this means that all information about research discoveries will be fully shared by the two firms.

I.2 Research Design Co-ordination

In the case where the RJV operates two laboratories, and where there is some potential complementarity between the research paths that each laboratory can pursue, the RJV designs the research strategies to be pursued by each laboratory in such a way as to maximise the potential complementarities.

(II) R&D Co-ordination

Here the RJV chooses the amount of R&D to do in each laboratory so as to maximise expected joint profits. That is R&D is chosen in a cooperative rather than a non-cooperative fashion. This decision is made taking account of the research decision decisions taken at the previous stage, and anticipating the research output information-sharing decisions to be taken at the subsequent stage.

This aspect of RJV decision-making is self-explanatory, and has been the focus of virtually all the analysis of RJVs to date.

(III) Research Output Information Sharing

The RJV has to decide how much information will be shared depending on what discoveries are made by each of the firms in the RJV.

Intuitively, by operating in this way the RJV can potentially address most of the market failures referred to above.

(b) Through II and III it can reduce non-strategic underinvestment since the firms in the RJV will base decisions on the amount of R&D on the benefit to the group rather than to the individual firm.

(c) Also through II and III it can reduce the strategic overinvestment, since firms will no longer be trying to innovate ahead of their rivals.

\(^7\) Martin (1998) and Vonortas (1994) use the terms operating entity joint venture and secretariat joint venture to refer respectively to the cases where firms operate 1 or 2 labs.
(d) Through I.1 it may be able to avoid duplication by undertaking all R&D in a single lab. Even if the RJV decides to operate two independent labs, the reduction in *strategic overinvestment* will ameliorate the needless duplication.

(e) Through I.2 and III it can increase the extent to which complementarities are exploited.

(f) While through II and can also increase R&D spending to better realise these complementarities.

(g) Finally through II and III, not only is the RJV likely to increase the amount of *research output information* that is shared, but this sharing will no longer be perceived as an externality, thus reducing the *spillover under-investment effect*.

Notice that the only market failure not addressed by the RJV is (a) – the *undervaluation effect*.

In order to better organise the literature on RJVs within this intellectual framework, in the next section I set out a formal model of RJV behaviour which draws together all these ideas.
Section 2  The Model

There are two firms. The products they produce can be either substitutes or complements. For illustrative purposes we can think of the demands being given by

\[ p_i = a - x_i - sx_j, \quad i = 1, 2, \quad j \neq i, \quad -1 \leq s \leq 1 \]

where \( x_i, \ i = 1, 2 \) denotes the consumption of good \( i \), and \( s \) denotes the degree product substitutability \( (s > 0) \) or complementarity \( (s < 0) \).

Each firm starts with an initial technology which gives it constant marginal costs of production \( \bar{c}, \ a > \bar{c} > 0 \). The two firms spend money on R&D in order to make a discovery about some new lower cost technology. The probability of each firm’s making this discovery depends solely on the R&D it does. Denote this R&D technology by the cost function \( C(p) \), where \( p, \ 0 \leq p \leq 1 \) denotes the probability of discovery.

Assume
\[
\text{C (i) } C(0) \geq 0; \quad C'(0) = 0; \\
\text{C (ii) } C'(p) > 0. \quad 0 \leq p \leq 1; \\
\text{C (iii) } p \to 1 \Rightarrow C'(p) \to \infty.
\]

Assumption C(i) allows for fixed costs, though I assume that these are sufficiently small that both firms would undertake R&D in any non-cooperative equilibrium.

If one firm alone makes a discovery it lowers its costs to \( \bar{c}, \ 0 < \bar{c} < \bar{c} \). Let \( q = \bar{c} - \bar{c} \) denote the quantum of progress made. Assume that, through spillovers (i.e. involuntary information leakage), a fraction \( \delta, \ 0 \leq \delta < 1 \) of this progress becomes available to the firm that has not made a discovery. Assume also that through voluntary information revelation, a fraction \( \delta^{10}, \ \delta \leq \delta^{10} \leq 1 \) of this progress can be made available to the firm that has not discovered.

If both firms make a discovery then the total quantum of progress made by each, \( t \), is given by

\[ t = \tau(q, r; \gamma) \]

where \( r, \ 0 \leq r \leq q \) is the amount of progress each firm receives from the other, and \( \gamma, \ 0 \leq \gamma \leq \infty \) is a parameter reflecting the degree of complementarity/substitutability of the research discoveries made by the two firms.

I assume that \( r = \kappa \delta^{11} q \). 

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Here, $\kappa$, $0 \leq \kappa \leq 1$ is the degree of research design co-ordination between the research paths pursued by the two labs, and $\kappa$, $0 \leq \kappa < 1$ is the minimum amount of co-ordination achieved haphazardly in the non-cooperative equilibrium. For expositional simplicity I will assume throughout the rest of the paper that $\kappa = 0$.

$\delta_{11}^i = \text{MIN} \left[ \delta_i^{11}, \delta_i^{11} \right]$, where $\delta_i^{11}, \delta \leq \delta_i^{11} \leq 1$ is the amount of information voluntarily shared by firm $i$ if both firms discover. This formulation captures the idea that it is the mutual interchange of information that enables firms to benefit from each other’s research.

This formulation highlights the fact that the benefit that one firm can make from the progress made by the other depends on both the amount of information which they mutually exchange and on their ability to co-ordinate their research plans in advance.

A precise functional form for the function $\tau(.)$ is given in Katsoulacos and Ulph (1998). For expositional simplicity I just note two special cases on which I will focus throughout the paper.

**Research Discoveries are Perfect Complements**

This arises when $\gamma = \infty$, in which case

$$\tau(q,r;\infty) = q + r = q + (\kappa \delta)q.$$

Thus to the extent that any firm can benefit from the progress made by the other, this just adds to the progress which it makes itself. This is the assumption that is made in virtually all the literature.

**Research Discoveries are Perfect Substitutes**

This arises when $\gamma = 0$ in which case,

$$\tau(q,r;0) = \text{MAX} [q,r].$$

Notice that, given our assumption that $r \leq q$ this implies that $t \equiv q$ so each firm’s progress is independent of anything it might learn from the other. This captures precisely the idea that firms are just duplicating each other’s discoveries.

Suppose that the market equilibrium is Cournot. Let $\pi(\alpha,\beta;s)$ be the Cournot equilibrium operating profits of a firm whose marginal costs are $\alpha$ when the marginal costs of the other firm are $\beta$ and the degree of product substitutability/complementarity is $s$. For simplicity, in what follows the explicit dependence of profits on $s$ will be suppressed.
Using this notation, we can then define the following profits conditional on whether or not each firm has discovered, and conditional on what R&D co-ordination and information-sharing decisions have been made.

(i) Neither firm discovers

Let \( \pi^{00} = \pi(\tilde{c}, \tilde{c}) \) be the profits of each firm and \( \Sigma^{00} = 2\pi^{00} \) their combined profits.

(ii) Only 1 firm discovers, and a fraction \( \delta^{10}, \delta^{10} \leq \delta^{10} \leq 1 \) of information is shared

Let \( \pi^{10}(\delta^{10}) = \pi(\tilde{c}, \tilde{c} - \delta^{10} q) \) be the profits of firm that has discovered; 
\( \pi^{01}(\delta^{10}) = \pi(\tilde{c} - \delta^{10} q, \tilde{c}) \) be the profits of firm that has not discovered; and 
\( \Sigma^{10}(\delta^{10}) = \pi^{10}(\delta^{10}) + \pi^{01}(\delta^{10}) \) be their combined profits.

\( \pi^{10}(.) \) is a strictly decreasing function of \( \delta^{10} \) if \( s > 0 \), and a strictly increasing function if \( s < 0 \). \( \pi^{01}(.) \) is a strictly increasing function of \( \delta^{10} \) whatever the value of \( s \). \( \Sigma^{10}(.) \) is a strictly concave function of \( \delta^{10} \).

(iii) Both firms discover.

Let \( \pi^{11} = \pi(\tilde{c}, \tilde{c}) = \pi^{10}(1) = \pi^{01}(1) \) denote the profits of each firm if (a) both discover and research paths are perfect substitutes \( (\gamma = 0) \); (b) both discover, research paths are perfect complements \( (\gamma = \infty) \) but no co-ordination has taken place – i.e. \( \kappa = 0 \). Notice that these are also the profits that each firm would make if only 1 firm discovered but information as fully shared. Let \( \Sigma^{11} = 2\pi^{11} \) be the combined profits of the two firms.

Notice that the function \( \pi[\tilde{c} - (1 + \kappa \delta^{11})q, \tilde{c} - (1 + \kappa \delta^{11})q] \) is a strictly increasing function of \( \kappa \delta^{11} \). It follows that, when research discoveries are complements, the RJV would want to fully co-ordinate and fully share information. So let \( \pi^{22} = \pi(\tilde{c} - 2q, \tilde{c} - 2q) \) be individual firm profits in this case and \( \Sigma^{22} = 2\pi^{22} \) be combined profits.

Having thus specified the model, we can now examine both the non-cooperative and the cooperative (RJV) equilibrium.

0 Non-Cooperative Equilibrium

Since, by assumption, no research design co-ordination is possible, the only decisions that can be made are those on R&D per firm and on the sharing of research output information when only one firm has discovered. As usual we analyse these backwards.
A.III Research Output Sharing

What happens here depends very much on what assumptions are made, for example whether licensing is possible, whether it is possible for firms to share information freely, or whether information-sharing is impossible.

Consider first the possibility that licensing is possible.

Let \( v^s(\delta) = \pi^{10}(\delta) - \pi^{11} \) be the minimum price which the licensor (seller) is willing to accept for licensing the discovery, and \( v^b(\delta) = \pi^{11} - \pi^{10}(\delta) \) be the maximum amount the licensee (buyer) is willing to pay for a licence. If goods are substitutes \((s > 0)\) then \( v^s(\delta) \) is positive and strictly decreasing, while if goods are complements \((s < 0)\), it is negative and strictly increasing. \( v^b(\delta) \) is positive and strictly decreasing.

Licensing will arise if \( v^s(\delta) > v^b(\delta) \), i.e. if \( \Sigma^{11} > \Sigma^{10}(\delta) \). This is always satisfied when goods are complements \((s < 0)\). If goods are substitutes \((s > 0)\) then licensing will arise when the scope for exercising monopoly power through withholding information is small. This will happen when the technical advance, \( q \), is small and/or when intellectual property rights are not too tightly enforced – i.e. when \( \delta \) is large.

If we assume that the bargaining strength of the licensor is \( \phi \), \( 0 \leq \phi \leq 1 \) then the licence fee is

\[
F = \phi \cdot v^b(\delta) + (1 - \phi) \cdot v^s(\delta)
\]

(1)

If licensing is not possible, but it is possible for information to be given away freely, then this will happen when goods are complements, but not when they are substitutes.

A.II R&D Co-ordination

It is useful to start with the case where in stage III firms give information away free of charge. Then the first-order condition for the symmetric non-cooperative equilibrium \( p \) is

\[
(1 - p)[\pi^{11} - \pi^{00}] = C'(p)
\]

(2)

The LHS is the marginal incentive to increase \( p \) and the RHS is the marginal cost.

The incentive here is the non-strategic incentive, since, with information freely shared, neither firm is trying to innovate ahead of the other. Notice that, as we would expect, the spillover parameter \( \delta \) has no effect on this equilibrium.

If information is not shared then the equilibrium condition becomes
whereas if information is sold under licence it becomes

\[ F + (1 - p)(\pi_{11} - \pi^{00}) = C'(p) \]

i.e.

\[ \{p \nu^b(\delta) + (1 - p)\nu^s(\delta)\} + (1 - p)(\pi_{11} - \pi^{00}) = C'(p). \]  

(4)

The first term on the LHS of (3) and (4) is the **strategic investment incentive** since it reflects the gains that a firm obtains by innovating ahead of its rival, in a situation where only one of them can innovate. For example, in the case of licensing, it will be able sell at the fee \( F \) if the rival fails to innovate (and it does) but will avoid having to pay the fee \( F \) if it fails to innovate (and its rival does). So the strategic incentive is \( F \) whatever the probability of discovery.

As noted above, if goods are substitutes, the strategic incentive is positive and strictly decreasing in the spillover parameter \( \delta \).

### 1 Co-operative (RJV) Equilibrium

Again we solve the equilibrium backwards.

**B.III Research Output Information Sharing**

As noted above, if research discoveries are complements, then the RJV will choose maximal research design co-ordination \( (\kappa = 1) \) in stage 1, and, given this will want to maximally share information when both firms discover, so \( \delta_{11} = 1 \).

However, if only one firm discovers the RJV will share information only if \( \Sigma^{11} > \Sigma^{10}(\delta) \). So, if licensing is available, and if research paths are perfect substitutes - so effectively, there is no information to be shared if both firms discover - then the RJV performs no better than the non-cooperative equilibrium at research output information-sharing.

**B.II R&D Co-ordination.**

The analysis here has to be split into two cases depending on the number of labs which the RJV operates.

**B.II.1 One Lab**
If, at stage I, the RJV decides to operate a single lab, then no complementarities can be exploited, and, by assumption, information is fully shared. So the decision about how much R&D to do, is characterised as follows.

Let

\[ V^1 = \text{MAX} \; P \sum^{11} + (1 - P) \sum^{00} - C(P) \]

be the expected present value of the RJV with one lab.

The f.o.c. for this is

\[ \Sigma^{11} - \Sigma^{00} = C'(P) \]

or

\[ 2(\pi^{11} - \pi^{00}) = C'(P) \]  \hspace{1cm} (5)

Comparisons with the conditions (2) – (4) in the non-cooperative equilibrium are not particularly useful since they all involve operating two labs. So let us turn to that case

B.II.2 Two Labs

Suppose that, at stage I, the RJV decides to operate two labs. Then the outcome at this stage depends on whether or not research paths are complements, and on whether or not, at Stage III, information is fully shared when only one firm discovers.

Then

\[ V^2 = \text{MAX} \; p^2 \Sigma^{11} + 2p(1-p)\text{MAX}[\Sigma^{11}, \Sigma^{10}(\delta)] + (1 - p)^2 \Sigma^{00} - 2C(p) \]  \hspace{1cm} (6)

is the expected present value of the RJV when it operates two labs and when research paths are perfect substitutes, while

\[ V^2 = \text{MAX} \; p^2 \Sigma^{22} + 2p(1-p)\text{MAX}[\Sigma^{11}, \Sigma^{10}(\delta)] + (1 - p)^2 \Sigma^{00} - 2C(p) \]  \hspace{1cm} (7)

is the expected present value of the RJV when it operates two labs and when research paths are complements.

To more fully understand the implications for RJV performance, let me concentrate here on the case where \( \Sigma^{11} > \Sigma^{10}(\delta) \) and so information is fully shared at stage III. The analysis of the case where information is not shared when only one firm discovers is given in the Appendix.
Perfect Substitute Research

From (6) the first-order condition for RJV profit-maximisation is

\[
2\{(1 - p)(\pi^{11} - \pi^{00})\} = C'(p)
\]

(8)

To understand the implications of this, consider first the case where licensing is impossible, but goods are complements, so, in the non-cooperative equilibrium firms would be willing to freely share information. If we compare (8) to (2) we see then that the incentive to undertake R&D has increased because the RJV internalises the beneficial effects of information sharing on the profits of both firms. Thus the RJV does indeed ameliorate the non-strategic underinvestment effect - problem (b) in the initial list of market failures. Essentially it does this through internalising the externality – problem (g).

In all other cases the non-cooperative equilibrium will be characterised by (3) or (4) depending on whether or not licensing is possible. By comparing (8) with (3) or (4) we see then that the RJV has had two effect: (i) it has removed the strategic investment incentive - problem (c); (ii) as noted above, it has internalised the information-sharing externality – problem (g). The first effect will tend to reduce the amount of R&D the RJV does, the second to increase it, so it is not at all clear on balance whether the RJV does more or less R&D. This point that has long been recognised since the classic article of d’Aspremont and Jacquemin (1988).

Complementary Research

From (7) the first-order condition for profit maximisation now becomes

\[
2\{p(\pi^{22} - \pi^{11})\} + 2\{(1 - p)(\pi^{11} - \pi^{00})\} = C'(p)
\]

(9)

The new term at the start of the LHS of (9) indicates that in addition to the effects mentioned above the RJV now has the additional benefit of ameliorating the under-exploited complementarities under-investment effect – market failure (f) in our initial list.

B.I Research Design Co-ordination

There are two aspects to research design co-ordination.
B.I.1 Exploiting Complementarities

If research paths are complements, then, by co-ordination of strategies, the RJV can design the research paths so as to maximise these complementarities, i.e., can set $\kappa = 1$. This has three effects.

By comparing (7) with (6) it has the direct effect of raising the expected profits of the RJV (if it operates two labs) for any given level of R&D. Thus it overcomes the under-exploited complementarities effect – market failure (e).

As noted above this has the further effect of encouraging the RJV to do more R&D – which further increases the value of operating two labs.

This brings us to the second research design issue:

B.I.2 Choosing the Number of Labs to Operate.

The RJV will make this decision by a straightforward comparison of $V^1$ and $V^2$. There are two effects at work here. To the extent that the research paths are complementary and the RJV maximally exploits these, this will increase the incentive to operate two labs.

The second issue is that of avoiding duplication – market failure (d). This issue is most acute when research paths are perfect substitutes and when the RJV chooses to share information. However, as noted by Katsoulacos and Ulph (1998a&b), even in this case, there is no automatic presumption that the RJV will necessarily choose to operate a single lab. If R&D were non-stochastic, then, in the circumstances just outlined, the RJV would certainly operate a single lab. Given the stochastic nature of R&D, however, there can be some benefit to operating two labs, since it increases the chances that at least one succeeds.

When the RJV decides not to share information, or, as noted, when there are complementarities then other factors come into play favouring the operation of two labs.

Thus, in summary, in this section I have provided a model/framework within which to view the operation of RJVs. Within this framework we see how an RJV may be able to address market failures (b) – (g) outlined in the previous section.
Section 3 Review of the Literature

In this section I will review the literature on Competition, Innovation and RJVs and, in particular, the contribution made to this literature by work undertaken in this TSER project. The latter works are indicated by having the names of the authors in bold. The review does not aim to be exhaustive, but rather to give an overview of the main developments in the field so that the reader can better understand the contribution made by the work of the TSER.

I will divide the review into a number of sections.

The first will examine the performance of RJVs, taking the number of firms in the RJV as fixed and assuming that firms act competitively in the product market. I will then examine the literature on the optimum and equilibrium size of an RJV, and the related literature on RJV membership. The third part will review the link between competition and RJV behaviour. The fourth part of this section will examine work on the evaluation of RJVs.

The final section of the review will cover some work done on the link between competition and innovation, but where there are no RJVs.

3.1 Performance of RJVs

A point of departure of many of the papers in the literature is the classic paper by d’Aspremont and Jacquemin (1988). They consider a model in which the products that firms produce are perfect substitutes. They employ a model in which R&D is non-stochastic and so both firms will discover for sure, and the research outputs are perfect complements. They assume that it is possible for firms to undertake some degree of R&D design co-ordination and information sharing in the non-cooperative equilibrium – so there can be a positive spillover between firms. However they also assume that this spillover is exactly the same when firms are in the RJV. They also assume that the RJV will always operate two labs. Essentially then all the decisions at Stages I and III of R&D decision-making are fixed, and the only decision they explore is that on the amount of R&D to be chosen. Thus the only role for RJVs here is on R&D co-ordination.

In the non-cooperative equilibrium this decision is made strategically, with R&D being chosen before output. Hence there are two effects at work. There is a strategic over-investment effect, and a spillover under-investment effect. The RJV will reduce the strategic overinvestment effect, but internalise the externality and so increase R&D. The overall effect on R&D spending will depend on which of these two effects dominates. The classic result obtained by d’Aspremont and Jacquemin is that when the spillover parameter is less than 50%, the RJV will undertake less investment than in the non-cooperative equilibrium. The RJV will raise investment when the spillover parameter is greater than 50%, and will therefore obviously do exactly the same amount when the spillover is exactly 50%.
De Bondt and Wu (1997), Suzumura and Goto (1997) and Beath, Poyago-Thotoky and Ulph (1998), extend this model by allowing for the possibility that through better co-ordination and information sharing the RJV may have a higher spillover than in the non-cooperative equilibrium, though the spillover parameter is still exogenously specified in both the cooperative and non-cooperative equilibria. Now the RJV will obtain any given R&D outputs (levels of cost reductions) more cheaply than in the non-cooperative equilibrium. Indeed, compared to the non-cooperative equilibrium it may achieve greater R&D outputs with a smaller total expenditure on R&D. An RJV may achieve more R&D outputs than the non-cooperative equilibrium, even when the spillovers are less than 50%.

Roller, Tombak and Siebert (1997) allow for possibility that firms produce complementary products, and notice that this makes R&D investments strategic complements, but do not explore the possibility of voluntary information-sharing in the non-cooperative equilibrium. Empirical work by Cassiman and Veuglers (1998)

In a series of papers, Katsoulacos and Ulph (1998a, b & c) have extended the above framework considerably. They have recognised that the “spillover” that appears in the above models reflects two different decisions – research design co-ordination and information-sharing – and have endogenised both decisions in both the cooperative and in the non-cooperative equilibrium. They then recognise that it is important to make many other distinctions that are not always made in the literature. In particular in the model presented in Katsoulacos and Ulph (1998b) they allow for

(a) products to be complements or substitutes;
(b) process or product innovation;
(c) a very general degree of substitutability/complementarity between research outputs;
(d) the possibility that the RJV may choose to operate just a single lab.

Some of the main conclusions to emerge from this analysis were:

(I) When products are complements firms may be able to achieve full research design co-ordination and information-sharing in the non-cooperative equilibrium.

(II) RJVs may choose not to fully share information - and indeed will do so for anti-competitive reasons.

(III) In particular RJVs may choose to operate a single laboratory to avoid information-sharing.

These findings raise serious doubts about the welfare gains to be had from RJVs – a topic to which I will return later.

There are three main differences between the model set out in Katsoulacos and Ulph (1998b) and the framework developed in the previous section.

(A) In Katsoulacos and Ulph (1998b) no allowance is made for the possibility of licensing in the non-cooperative equilibrium.

(B) Katsoulacos and Ulph (1998b) assume that it is possible for an RJV to operate
a single lab and yet not have that lab share information. This may be a rather odd assumption, in that typically when an RJV operates a single lab, this is staffed by scientists from each firm. Indeed such an arrangement may be precisely a device to ensure that information-sharing is achieved within the RJV. In the framework set out in the previous section, I make the opposite assumption that with a single lab full information-sharing is achieved.

(C) Katsoulacos and Ulph (1998b) model research design co-ordination as a parameter that each firm can choose independently, and which affects the usefulness of their research to the other firm.

In the framework developed in the previous section I have argued that research design co-ordination is an essentially cooperative activity that requires the exchange of a great deal of information and mutual planning prior to undertaking any R&D, and that such co-operation would normally be precluded under competition policy. Within such a framework one of the great benefits of RJVs – and hence of competition policy which gives exemption to RJVs – may be precisely that it allows this research design co-ordination to take place.

In an interesting paper Klette and Moen (1998) reflect on the role of technology policy in promoting the development of general purpose technologies (GPTs) in which such complementarities are rife. They argue that there are number of strands in the theoretical literature that suggest that firms may indeed be able to undertake a considerable amount of co-ordination through normal market relationships, and provide evidence that this can indeed happen. However, they also point to arguments and evidence that suggest that this co-ordination is not necessarily achieved through normal market relationships.

This seems to me to be one of the key areas for further research – both theoretical and empirical. In order to fully evaluate the role of RJVs, we really need to know in more detail precisely how much and what kind of co-ordination is achievable through non-cooperative, non-market means.

While I think that the work referred to above has helped us develop a framework for thinking about RJVs which is a considerable advance on existing models, there are still a considerable number of weaknesses.

- In their work Katsoulacos and Ulph (1998a,b&c) do not explain how any information-sharing agreements within RJVs get enforced – particularly in the case where the RJV operates two labs. Recent work by d’Aspremont, Bhattacharya and Gerard-Varet (1998) explore the issue of information-extraction in greater depth – particularly for the case of intermediate discoveries.
- The model assumes that there are just two firms who comprise the entire industry.
- The analysis follows the earlier literature in assuming that firms will act competitively in the product market.

I now review some recent literature on the last two issues.
3.2 RJV Size and Membership

Suzumura and Goto (1974), Poyago-Theotoky (1995), De Bondt and Wu (1997) have allowed the possibility that there may be many firms in an industry, not all of whom join an RJV. They have examined the issue of whether the equilibrium size of RJV is above or below the social optimum. An important issue that naturally arises in this context is that decisions taken by the RJV will affect the firms outside the RJV, but will typically be ignored by the RJV – creating an externality. The papers differ in their stability notions. Suzumura and Goto (1974) simply examine whether a grand coalition comprising all firms would be stable against defections of a single firm. They find that if the RJV has no information-sharing advantage – and so has the same spillover as the non-cooperative equilibrium then the grand coalition is unstable. However when the RJV can also promote greater information-sharing amongst its members then the prospects for stability are increased. De Bondt and Wu (1997) look at coalitions comprising less than the entire industry and here examine two types of stability – no insider should wish to leave, and no outsider should wish to join. As in Suzumura and Wu (1974), coalitions are unstable if the RJV has no information-sharing advantage over firms outside the RJV, but if there is such an advantage, then stable RJVs may form. The size of the stable coalition depends on the spillover. The larger the spillover, the smaller is the stable coalition, since outside firms can free-ride on the cartel. They find that the equilibrium (stable) size of cartel may be above or below the optimum size. Poyago-Theotoky (1995) uses a different stability condition whereby the RJV can block entry. Now the equilibrium size of RJV is too small.

All these papers consider the case of a single group of firms in a single industry. Ulph (1991) examines two groups of firms located in different countries where, for as a consequence of previous R&D success, one group of firms currently has a technological advantage over the other. He considers a model in which, in a non-cooperative equilibrium, the firms in the technologically backward country would fall further behind, and examines whether the formation of an RJV by a subset of firms in this “backward” country could help regain a technological lead. He shows that this could happen but that, as in Poyago-Theotoky (1995) the equilibrium size of RJV could be below the optimum.

A somewhat related literature is that on RJV membership. Here, the aim is to explain the types of configurations of firms observed in RJVs. The most systematic attempt at modelling this is the recent paper by Roller, Tombak and Siebert (1997). As in d’Aspremont and Jacquemin (1988) there are just two firms, so the size of the RJV is fixed, and research outputs are perfect complements. As in d’Aspremont and Jacquemin (1988) spillovers are fixed so, as they note, there are no real opportunities here for RJVs to exploit complementarities. However, unlike d’Aspremont and Jacquemin (1988) firms can differ in their initial costs, and the products they produce can be complements rather than substitutes. They conclude that the gains from RJV formation are highest when: (i) R&D spillovers create free rider problems; (ii) duplicative R&D creates opportunities for cost-sharing; (iii) firms produce complementary products; (iv) firms are of fairly similar size.
While these findings are of some interest, and seem to be borne out by the data, there are a number of problems with this analysis.

(a) As Roller, Tombak and Siebert note - the RJV is unable to really exploit complementarities.
(b) While they discuss the gain from avoiding duplication, the R&D is perfectly complementary – so there is no real duplication taking place. Moreover the RJV always continues to operate two labs.
(c) As noted above, firms producing complementary products may have considerable incentives to share information and carry out co-ordination in the non-cooperative equilibrium, and this is not allowed for.
(d) Some caution has to be exercised in discussing how the size of asymmetries affects incentives to form an RJV. Asymmetries can be increased in many different ways, and these can have differential impacts on the incentives to join an RJV. At best one can get *ceteris paribus* conclusions about, say, increasing asymmetries keeping the mean value of initial costs constant - see for example Long and Soubeyran (1997).

### 3.3 Interaction Between RJVs and Product Market Competition

So far I have followed much of the literature in assuming that although firms might collaborate in the R&D stage of the game, they compete in the product market stage. An issue of considerable policy concern is that of cooperation in R&D might enable firms to cooperate in the output stage – see, for example, Suzumura and Goto (1994) for a discussion of this issue.

However since the emphasis has been on how RJVs may improve dynamic efficiency, this potential impact of RJVs on static efficiency has received little formal analysis. One paper which undertakes such an analysis is that by Martin (1995). He uses a model in which firms are involved in an ongoing process to develop some new technology/product. If firms have joined an RJV voluntarily, it can only be because their profits are higher inside the RJV than outside it. But then the threat to dissolve the RJV can be used as a trigger strategy to sustain higher prices while the RJV is still trying to discover the new technology.

As noted above the work by Katsoulacos and Ulph (1998 a, b & c) provides an alternative route by which RJVs may affect post-discovery profits – for they show that the RJV may not always fully share information. Whenever this happens it does so for anti-competitive reasons - the RJV wishes to prevent the market from becoming too competitive by having firms with identical costs/products.

A more recent paper by Beath and Ulph (1999) extends the framework used in all the literature to date by allowing an entry stage of the game to occur after the R&D decisions have been taken, but before the price/output stage of the game. The model is an extension of that used by Katsoulacos and Ulph (1998b&c). The idea here is that firms are located in different countries/markets. There are trade costs of a firm located in one
market serving the consumers in the other market. If one firm alone discovers a new low-cost technology, and does not share this discovery with the other firm, then its technological advantage may enable it to overcome the trade cost disadvantage and enter the other firm’s market. However, by sharing information, this removes the discovering firm’s technological advantage, and may therefore prevent entry. Here then full information-sharing is used as a commitment device to prevent subsequent entry – even when this decision is made in a non-cooperative fashion outside the RJV. However, as Beath and Ulph (1999) note, this entry prevention is not really anti-competitive, since, because costs are lowered, welfare is higher than it would have been had information not been shared and entry taken place.

An interesting recent paper by Martin (1998) looks at the reverse linkage from product market competition to innovation and the performance of RJVs. Of course a major instrument of competition policy that bears on innovation and RJV performance are the exemption clauses that allow cooperation on R&D. But this ignores the many other instruments of competition policy like regulation. In his paper Martin explores the effects of having tighter regulation in the form of a lower guide price to trigger regulatory investigation. He employs a pure tournament model in which research paths are perfect complements. Research joint ventures are assumed to fully share information, although they cannot influence the extent of the (input) spillovers.

He shows that although tighter regulation lowers profits, it lowers pre-discovery profits more than post-discovery profits and so can increase the incentive to innovate. He also shows that excessively tough competition policy can have negative effects on welfare – since it encourages excessively rapid innovation. Welfare is highest when competition policy is moderately tough, there is an RJV operating two labs with high spillovers.

This is an interesting line of research, which warrants further work drawing on the RJV framework outlined in Section 2.

This brings us to an analysis of the work done on evaluating RJVs and RJV policy.

3.4 The Evaluation of RJVs and of RJV Policy

There has been a considerable amount of discussion of RJVs and of RJV policy, but relatively little in the way of a careful welfare evaluation – either theoretically or empirically.

Explicit theoretical welfare evaluations of RJVs have appeared in the papers by Kamien, Muller and Zang (1992), Suzumura and Goto (1994), Martin (1994 & 1998), De Bondt and Wu (1997). However these suffer from a number of problems.

Thus the papers by Kamien, Muller and Zang (1992), Suzumura and Goto (1994), De Bondt and Wu (1997) all draw on the original d’Aspremont and Jacquemin framework with spillovers that are exogenously specified; research paths that are perfect
complements, substitute products, symmetric RJV equilibria. Thus, in relation to the framework developed in Section 2, they suffer from two major weaknesses.

(i) They fail to give full scope to the range of market failures that RJVs might address and the range of methods they might use to do so – such as research design coordination.

(ii) They do not explore the range of methods that firms might employ to undertake coordination and information-sharing in the non-cooperative equilibrium.

The first failure means that they mis-state the possible achievements of RJVs, while the second means that they mis-state the counter-factual as to what happens under the non-cooperative equilibrium.

Suzumura and Goto (1994) explicitly recognise the limitations of their framework for addressing some of the potential benefits and disadvantages of RJVs. For example they point out that RJVs are sometimes thought to be harmful in that they reduce the amount of innovation – without recognising that in some cases this is precisely the source of benefit from an RJV.

Martin (1994) provides a good account of the conflicting views of the possible benefits that RJVs might confer. However this just confirms the views set out in Sections 1 and 2 of this paper. There are many different market failures that RJVs might potentially address – and that in order to have a full appreciation of the role they play, one needs a framework that recognises these many failures and the way in which RJVs may or may not address them. The welfare model that Martin uses to evaluate RJVs is somewhat different from those referred to above, in that his model is of a pure tournament and allows RJVs to operate either one or two labs. However, as in the previous papers referred to there is little recognition of the full role that RJVs might play, nor of possible alternative arrangements in the non-cooperative equilibrium.

The paper that comes closest to using the framework set out in section 2 to evaluate RJVs is that by Katsoulacos and Ulph (1998c). However, while it draws on the general framework of Section 2, the welfare evaluation covers a special case. Thus there are just 2 firms; they produce a homogeneous product, and their research discoveries are perfect substitutes. Thus there is potential needless duplication of research, but there is no scope for research design co-ordination to exploit complementarities. The RJV can decide whether to operate 1 lab or two labs, and whether or not to share information. Firms can choose whether or not to license information in the non-cooperative equilibrium.

In terms of information-sharing, notice that if firms choose to fully share information in the RJV, they will also licence in the non-cooperative cooperative equilibrium. Turning to the R&D coordination decision notice that when full information-sharing takes place then the RJV underinvests in R&D because of the under-valuation effect, while in the non-cooperative equilibrium there is strategic overinvestment. This leads to the following conclusions:
• When full information-sharing takes place then the RJV typically generates higher welfare than the non-cooperative equilibrium whenever the RJV chooses to operate a single lab. However, the non-cooperative equilibrium is typically welfare superior to the RJV when the RJV chooses to run two labs. This is because the combination of the under-valuation effect and the strategic over-investment effect tend to cancel out leading to the non-cooperative equilibrium producing a level of R&D spending that is closer to the social optimum.

• When information is not shared then the RJV can often do much worse than the non-cooperative equilibrium. This is because the overinvestment in the non-cooperative equilibrium means that the possibility that just one firm discovers (and so information is not shared) happens much less frequently than in the RJV.

As indicated, an important reason why RJVs perform rather badly is that, because of the undervaluation effect, they under-invest in R&D. As pointed out in Sections 1 and 2, RJVs alone cannot address this problem. This suggests that a combination of RJV and subsidy might be capable of achieving the welfare optimum.

Indeed a recent paper by Hinloopen (1998) has gone further and suggested that R&D subsidies by themselves can achieve the optimum. However this idea is developed in the d’Aspremont and Jacquemin (1988) framework where, effectively, there is only one thing to determine – the amount of R&D per firm. It is clear that in this context a single instrument – an R&D subsidy - can achieve the full optimum whether firms act cooperatively or non-cooperatively.

However in the framework developed here an R&D subsidy by itself will not achieve the full optimum – since it cannot induce the information-sharing and research design coordination. Katsoulacos and Ulph (1998a) investigate the implications of using subsidised RJVs, whereby firms only get the R&D subsidy if they join an RJV. They show that while a subsidy might have the beneficial effect of ameliorating the under-valuation effect; it may have two harmful effects. It could induce firms to operate two labs where they might otherwise have operated one, and so increase needless duplication. It may encourage firms to join an RJV to claim a subsidy where, in the non-cooperative equilibrium they were getting the information-sharing decisions and R&D decisions more or less right. We need more work on the use of a mixture of instruments.

The importance of these results is that they show that when a full account is taken of all the possible forms of behaviour in both the RJV and in the non-cooperative equilibrium, then it is far from obvious that RJVs are necessarily superior to non-cooperative methods of organising R&D.

In particular the analysis shows that it is important to recognise that RJVs may have anti-competitive effects. This is in contrast to much of the previous literature which either simply presupposes that RJVs are no less competitive than non-cooperative outcomes. This is because the literature focuses either on non-tournament models in which both firms
discover, or, as in Martin (1994, 1998) on tournament models in which the RJV is assumed to fully share information.

Of course one does not want to overstate this result, and a fuller evaluation of RJVs can only be undertaken once a much more systematic exploration has been undertaken of the full range of possible cases covered by the framework set out in Section 2. I will return to this point in the next section.

An interesting complementary study is that by Klette, Moen and Griliches (1998). This reviews the few (recent) empirical studies that have been undertaken to try to quantify the benefits of government sponsored programmes. These programmes often take the form of sponsoring R&D consortia (RJVs). In the light of these studies the authors try to develop a framework for undertaking such evaluations in the future. A number of important points emerge from their study.

- RJVs form for a number of reasons. In some cases the elimination of duplication is the primary motive, while in others it is the exploitation of complementarities. Any framework for evaluation has to recognise these.
- Some of the most important difficulties in undertaking empirical evaluations arise in determining the extent of true spillovers – i.e. unintended, unrewarded information leakages – as distinct from information transfers that are rewarded either through private payments or internalised through cooperative agreements. In essence this recognises that information transfers can be voluntary in both the cooperative and the non-cooperative equilibrium.
- They emphasise the importance of carefully establishing the counter-factual – what would have happened to firms had they not joined a particular programme. This corresponds to the discussion above of the importance of properly characterising the non-cooperative equilibrium.
- They emphasise that this problem has particular resonance in the case where the gains from the RJV might involve the exploitation of complementarities – since there is then an important issue as to whether firms might be able to exploit these through various private arrangements.

The thrust of this study is thus very similar to that emerging from the theoretical discussion above.

3.5 Innovation and Competition

A long-standing interest in the theory of innovation is the link between R&D competition and market structure. In general both of these are endogenous, with market structure both determining and being determined by the outcome of R&D competition.

In particular, we know from the literature on tournament races\(^8\) that there are two incentives at work determining the relative amounts of R&D that firms do: there is the

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\(^8\) See Beath, Katsoualcos and Ulph (1995) for an overview of this literature.
profit incentive (sometimes known as the displacement effect) and there is the competitive threat. The former is typically greater for the follower, the latter for the incumbent. To the extent that the profit incentive is the dominant incentive the outcome of R&D competition will be creative destruction or action/reaction. To the extent that the competitive threat is the principal incentive, the outcome will tend to be persistent dominance – though this is not guaranteed.

Theory predicts that when innovations are drastic then the profit incentive is the principal determinant of R&D, whereas for non-drastic innovations, it is typically the competitive threat.

Of course the outcomes of R&D competition are not determined by incentives alone. At least two other effects are at work.

The first is what is known as the “deep-pocket effect”. For a variety of reasons, internal sources of funds – retained earnings – may play an important role in funding R&D. Thus incumbent firms with higher levels of retained earnings may have an advantage over non-incumbents in funding R&D. Ceteris paribus this effect would tend to produce persistent dominance.

The second effect is what is known as “success-breeds-success” – see Dasgupta (1986). The idea here is that for a given level of R&D spending, firms that have recently been successful at innovation have a higher probability of success than unsuccessful firms. This may be because techniques that have been successful in making one discovery will also work in making related discoveries. Beath, Katsoulacos and Ulph (1995) provide a useful overview of this literature. As Dasgupta (1986) notes there is empirical support for this idea, though it does not figure very much in the theoretical literature where it is often assumed that firms have identical R&D cost functions. Again ceteris paribus this factor would tend to produce persistent dominance.

In an important recent study Blundell, Griffith, and Van Reenen (1998) have used panel data and some new developments in the estimation of dynamic count data models to control for unobserved firm-specific heterogeneity to try to test out the links between market structure and innovation. They control for the deep-pocket effect by including measures of cash flow and of total firm sales in the innovation equation, and show that there is a robust effect of market share on observable headcounts of innovations and patents. They interpret this as being consistent with idea that the competitive threat is the dominant incentive.

However the finding could also be consistent with “success-breeds-success”. To sort this out further, one would need to investigate more fully the structure of the links between innovation, R&D and market structure. Nevertheless this is a pioneering study with considerable scope for further research.
Section 4 Directions for Further Research

While the work undertaken in this TSER project has made important developments, it has equally identified many directions for further work. On the theoretical front we need to develop the framework sketched out in Section 2. There are a number of principal developments.

A) We need to understand much more fully the scope for R&D co-ordination through non-cooperative mechanisms.

B) More generally the literature has focused rather heavily on co-operation and complementarities between very similar firms – both being active in research and in the product market. We need to examine other types of complementarities and other types of institutions – e.g. links between universities and firms.

C) We need to extend the welfare evaluation to encompass the full range of possibilities allowed for in the model.

D) We need to couple the understanding of how firms behave in both the co-operative and non-co-operative equilibrium with an analysis of RJV membership. The question we really need to address is whether we should let private incentives alone determine which firms form an RJV, or whether we think that the strongest private incentives may not coincide with the highest social gains from RJV formation.

E) It would be a useful exercise to try to use the theoretical framework to more carefully guide the empirical gains from RJV formation.

These extensions all operate more or less within the existing model.

However there are two further areas for research which will require the development of significantly new models of RJVs.

I) As developed so far the theory treats R&D done by firms as a homogeneous entity – so all R&D is undertaken either independently or inside an RJV. What the existing theory has failed to properly grasp is the idea that firms are typically involved in a portfolio of research projects, and the issue they face is which projects they do alone, and which they do collaboratively.

II) Much of the literature focuses on the performance of RJVs once firms are already in an RJV. The smaller literature on RJV membership assumes that firms are fully informed about the firms with which they may or may not form a partnership. While it may be reasonable to think of firms in the same industry being fairly fully informed about each other, it is less clear that this assumption is valid when thinking about co-ordinating R&D across very different industries. Clearly a significant part of policy towards science parks, industrial districts is aimed at addressing these informational issues. I think the theory needs to take this more seriously.
Section 5  Conclusions

As indicated in the text it is somewhat premature to draw firm policy conclusions from the work undertaken here.

Nevertheless some important points have emerged which should be taken into account in policy thinking.

• The existing analytical framework for thinking about RJVs has under-stated the potential benefits of RJVs in correcting market failures, by focusing rather heavily on the role of RJVs in coordinating R&D, and ignoring their role in research design co-ordination and in information sharing.

• The existing literature has also failed to deal adequately with the question of how far some of these benefits can be handled through private contractual means. There is scope for considerably more work on this – particularly in connection with research design co-ordination. Preliminary work in the context where research paths are substitutes and so the only research design issue is the number of labs to operate, suggests that non-cooperative outcomes can welfare dominate RJVs in situations where RJVs choose to operate independent labs.

• We have also seen that RJVs may not always fully share information. Whenever they fail to fully share information this is for anti-competitive reasons. In this context non-cooperative arrangements may be welfare superior. This is not because they are any better at information-sharing, but because they are less prone to under-investment and so situations where only one firm discovers are less likely to arise. This points up the importance of the interaction between the information-sharing decision and the R&D decision.

• By themselves RJVs will not solve all the market failures associated with R&D. In particular they do not address the under-investment effect. This is an important part of the reason why, in the results reported above, RJVs may be welfare dominated by non-cooperative arrangements. This suggests that more attention needs to be paid to combinations of policy instruments like subsidies and RJVs. However, as indicated, subsidised RJVs are prone to other problems as well, so the correct solution is not just a simply subsidy to RJVs.
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Appendix: Performance of RJV When Information Is Not Shared

In this appendix I present the analysis of RJV R&D decisions when it operates two labs, but when, if only 1 lab discovers, information is not shared. This case arises when $\Sigma^{11} < \Sigma^{10}(\bar{\delta})$.

To understand what R&D decisions the RJV makes, let

$$\pi^{10}(\bar{\delta}) = \frac{1}{2} \Sigma^{10}(\bar{\delta}) = \frac{1}{2} \left[ \pi^{10}(\bar{\delta}) + \pi^{01}(\bar{\delta}) \right]$$

denote the profits that a firm would expect to make on average if only one of them discovered and information was not shared.

Also let $\bar{v}^s(\bar{\delta}) = \pi^{10}(\bar{\delta}) - \pi^{11} > 0$, $\bar{v}^b(\bar{\delta}) = \pi^{11} - \pi^{10}(\bar{\delta}) < 0$ denote the prices at which the firm would be willing to sell (resp. buy) the discovery. Notice that $\bar{v}^s(\bar{\delta}) < \nu^s(\bar{\delta})$, $\bar{v}^b(\bar{\delta}) < 0 < \nu^b(\bar{\delta})$.

In the case where research paths are perfect substitutes, the first-order condition for RJV profit-maximisation is

$$2 \left[ p \bar{v}^b(\bar{\delta}) + (1 - p)\bar{v}^s(\bar{\delta}) \right] + (1 - p)\left[ \pi^{11} - \pi^{00} \right] = C'(p)$$

In comparison with equation (3) in the main text - which characterises the R&D decision in the non-cooperative equilibrium when no information is shared - we see that the RJV has two effects

(i) it lowers the strategic investment incentive – which could indeed become negative;
(ii) by internalising decisions within the RJV it doubles the overall incentive.