PUBLIC POLICIES TOWARDS COOPERATION IN RESEARCH AND DEVELOPMENT

The European Union, Japan and the United States

Stephen Martin

Just where to draw the line between competition and cooperation among independent firms is a topic of perennial debate in the field of public policy towards private enterprise. US policy-makers have recently shifted that line substantially in the direction of cooperation, largely justifying the move with arguments to the effect that cooperation by rivals in research, development, and production will improve dynamic market performance without adversely affecting static market performance. Comparisons of US policy in this area with those of the European Union and Japan featured prominently in the discussion that led up to this decision.

I wish to suggest, first, that a balanced assessment of the economic analysis of technological progress calls for a more cautious approach to claims that interfirm cooperation in research and development will improve dynamic market performance than has been evident in policy circles; it also suggests that such cooperation is conducive to the exercise of monopoly power in product markets. Second, examination of EU and Japanese treatments of interfirm cooperation suggests that they are structured to maintain effective product market competition, incorporating safeguards that are absent from recently adopted US policy.

JOINT RESEARCH, DEVELOPMENT, AND PRODUCTION IN A MARKET SYSTEM

I begin with a review of what economic models and the economic literature have to say about market structure, cooperation regimes, and dynamic market performance. To foreshadow the main conclusions, formal models suggest that while there are some circumstances in which joint research, development, and production (henceforth, R&D&P) is socially
advantageous, it generally involves a trade-off between producer welfare and consumer welfare. Sometimes this trade-off will balance out in favour of consumers; sometimes it will not. Sometimes the net impact on social welfare will exceed that which would be produced by independent R&D and independent production; often it will not. Permitting joint R&DP ordinarily increases firms’ profits, but sacrifices the incentives, recognized since the work of Schumpeter, that product market rivalry provides to invest in innovation.

**Innovation race models: simulation results**

Innovation involves uncertainty in an inherent way. A decision to invest in the development of a new product or process means committing funds and resources in the short run for a pay-off that will come, if at all, in the long run. Such investments typically take place in a rivalrous 'market for innovation': a firm will understand that if it believes it is profitable to conduct research in a certain area, so will other firms. An R&D project may yield no commercially feasible results; it may be 'beaten to the punch' by a rival project.

Innovation race models describe static and dynamic market performance when firms invest current resources in hopes of being the first to develop, at an uncertain future time, a profitable innovation. The first firm to develop the innovation – the winner of the innovation race – gains an operating advantage over its rivals. That advantage translates into greater profits; exactly how much greater depends on the nature of product market competition, on the extent to which the winner can control use of the innovation (appropriability), and on the extent to which the legal regime permits cooperation, either in R&D or in R&DP.\(^1\,^2\)

The models that generate the simulation results reported below have a common structure (described formally in the appendices). Firms have the possibility of competing to discover a cost-saving innovation. Innovation is profitable, in an expected value sense: the first firm to discover the cost-saving innovation is able to produce at lower cost, and is able to license the use of the innovation, for a fee, to its rivals.\(^3\) There are externalities in the production of knowledge: firms benefit from the R&D of other firms, and their own R&D benefits other firms. If a firm undertakes R&D, it does so to maximize its expected present discounted value.

The simulation results describe various aspects of technological performance. Most directly related to technological advance are equilibrium firm R&D levels and the expected time to discovery, which vary depending on the cost of R&D and the extent, if any, to which firms are permitted to cooperate. Results also include expected firm values and a measure of consumer welfare, the expected present discounted value of consumers’ surplus.
In a market system, firms will invest in R&D only if doing so increases their value. Thus expected firm values determine whether or not R&D will occur in a market system. Similarly, in a market system, technological progress is valued not for its own sake but rather because it generates products that consumers find more satisfactory or production processes that deliver existing products to consumers at lower prices. Consumers’ surplus is an index of the extent to which consumers benefit from technological progress. Cost-saving innovation tends to result in lower prices, leaving consumers better off.

The essential trade-off at the heart of the debate over cooperative research, development, and production is between producer and consumer welfare. If firms are allowed to cooperate in the post-innovation product market, this will increase expected firm profit and firms’ incentive to invest in innovation. The resulting cost savings will leave society better off. But product-market cooperation translates into high prices, leaving consumers worse off. The net welfare impact of cooperation in research, development, and production is ambiguous. The alternative simulations discussed below give results for different market structures and cooperation regimes. This permits assessment of the implications of alternative cooperation regimes for static and dynamic market performance.

*Costly new product innovation*

Table 10.1 reports equilibrium outcomes, under alternative cooperation regimes, for a four-firm race to develop a new product. In relation to the size of the market, the fixed cost of setting up an R&D project is large.

Results are shown for two types of R&D cooperation and two types of product market regimes. An R&D joint venture implies that the four firms divide the cost of a single R&D project; with a patent pool, each firm carries

<table>
<thead>
<tr>
<th>R&amp;D</th>
<th>Prod</th>
<th>h</th>
<th>E(disc)</th>
<th>Firm value</th>
<th>Consumers’ surplus</th>
<th>Net social welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
<td></td>
<td>Never</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Joint</td>
<td>Ind</td>
<td>6.2703</td>
<td>0.1595</td>
<td>-1,707.28</td>
<td>28,158.68</td>
<td>21,329.56</td>
</tr>
<tr>
<td>Joint</td>
<td>Joint</td>
<td>6.3606</td>
<td>0.1572</td>
<td>1,144.11</td>
<td>8,519.90</td>
<td>13,096.33</td>
</tr>
<tr>
<td>Pool</td>
<td>Ind</td>
<td>2.3816</td>
<td>0.0807</td>
<td>-2,241.32</td>
<td>28,378.60</td>
<td>19,413.33</td>
</tr>
<tr>
<td>Pool</td>
<td>Joint</td>
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<td>0.0806</td>
<td>641.95</td>
<td>8,584.78</td>
<td>11,152.58</td>
</tr>
</tbody>
</table>

*Notes:* Column 1 indicates the nature of R&D competition, column 2 indicates the nature of product market competition; four firms; R&D cost function \( z(h) = 40000 + 10h + 1000h^2 \); demand intercept = 100; product differentiation parameter = 0.75; spillover parameter = 0.1; interest rate = 0.1; unit cost after discovery = 25.
out its own R&D project. In either case, all firms have access, upon
discovery, to the technology used to produce the new product.

After discovery, each firm produces its own variety of the product.
Varieties are close but imperfect substitutes. Price is the post-discovery
decision variable. Independent product market behaviour implies that each
firm non-cooperatively sets the price that maximizes its own profit, taking
the prices of other firms as given. Joint product market behaviour implies
that firms set prices to maximize total profit.

The (potential) product is completely new: the first row of Table 10.1
shows values if the market never comes into existence (which explains why
net social welfare is zero). Row 2 shows results if firms jointly finance an
R&D project, then act independently after discovery. Joint R&D implies that
the cost of the R&D project is divided four ways. Independent decision-
making in the post-innovation market means firms behave rivalrously,
pricing to maximize only their own profit, taking the prices of other firms as
given. A consequence is the relatively high levels of consumers' surplus:
given that the market comes into existence, consumers are well served by
product-market rivalry. Net social welfare is the sum of firms' expected
values and expected consumers' surplus. This is positive in row 2, showing
that society would be better off if firms' expected losses were covered by a
subsidy and the market supplied by independent firms after discovery. There
are many practical difficulties associated with such subsidies, however.

But in this example innovation is so costly, relative to the size of the
market, that it is not profitable for firms to innovate if they must behave
independently after discovery, even though joint R&D means sharing R&D
costs: expected firm value in row 2 is negative.

Row 3 of Table 10.1 shows results if firms are permitted to maximize
joint profit in the post-innovation market. Such cooperation leaves con-
sumers worse off than they would be under the row 2 regime, but better off
than if the product is never developed at all (and under a market system
without subsidies, this is the relevant alternative). Observe also that the
intensity of the R&D product \( (h) \) is greater, and expected time to discovery
somewhat smaller, in row 3 than in row 2. Greater expected profit in the
post-innovation market is an incentive to increase investment in innovation.

Rows 4 and 5 of Table 10.1 correspond to rows 2 and 3, but assume that
firms set up a patent pool, not a joint venture. A patent pool implies that each
firm sets up its own R&D project, and all firms have access to the results of
the first success. Observe that each firm, in equilibrium, invests less in R&D
than with an R&D joint venture – \( h \) is substantially smaller in row 4 than in
row 2, for example. But because there are four independent projects, expected
time to discovery is substantially smaller with a patent pool than with an
R&D joint venture. Parallel research projects improve technological
performance. Comparing rows 4 and 5, we see once again that product-
market cooperation makes it profitable for firms to invest in innovation.
Aside from the fact that expected time to discovery is less under a patent pool than in an R&D joint venture, results for the two cases are qualitatively similar. In what follows, I report results only for R&D joint ventures.

For the case of very costly new-product innovation, consumers are better off with collusive supply of the new product than without the product at all. Allowing static product market cooperation can improve dynamic product market performance, if innovation is costly and provides a new product. It is rare, however, that a product is completely new. Nor is all innovation prohibitively costly, in relation to the benefits it offers. Turn, then, to simulations of the market structure–dynamic performance relationship for cost-saving innovation in the production of existing products.

**Monopoly research and development**

The market for innovation is plagued with imperfections. A policy of allowing joint production after innovation is a policy of allowing static monopoly power as a remedy for these imperfections. But product market power is not a general cure-all for imperfections in the market for innovation. Even complete monopoly will not ensure some socially desirable innovation; by contrast, oligopolistic rivalry in innovation will sometimes support socially desirable research and development that monopoly will not.

Typical results for cost-saving innovation by a monopolist are shown in Table 10.2. In this example, the innovation leads to a reduction in unit cost from 40 to 25, in a market where a price of 100 would drive the quantity demanded to zero. The table reports results for four cases: no R&D and progressively less costly R&D.

In a market system, a firm will actually undertake an R&D project only if the expected pay-off from doing so exceeds the expected pay-off from using the existing technology and avoiding the cost of running the R&D programme. From row 1 of Table 10.2, if the monopoly supplier of this market does not innovate, its expected value is 9,000. Rows 2 and 3 show results if the fixed cost of R&D is relatively high (20,000 and 10,000, respectively). When the fixed cost of R&D is this high, even complete monopoly power

<table>
<thead>
<tr>
<th>Fixed cost ($F_R$)</th>
<th>$h$</th>
<th>$1/h$</th>
<th>Firm value</th>
<th>Consumers' surplus</th>
<th>Net social welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>No R&amp;D</td>
<td>Never</td>
<td>9,000.00</td>
<td>4,500.00</td>
<td>13,500.00</td>
<td></td>
</tr>
<tr>
<td>20,000</td>
<td>4.4294</td>
<td>0.2258</td>
<td>5,193.75</td>
<td>6,975.37</td>
<td>12,169.11</td>
</tr>
<tr>
<td>10,000</td>
<td>3.1427</td>
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<tr>
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<td>6,923.47</td>
<td>16,479.05</td>
</tr>
</tbody>
</table>

*Notes: $c_1 = 40; c_2 = 25; z(h) = F_R + 10h + 1000h^2$; interest rate =0.1.*
will not make investment in innovation profitable: the monopolist's maximum value with R&D, in rows 2 and 3, is less than its value without R&D. Row 2 shows a case in which the cost of innovation is so high that innovation is socially undesirable as well as privately unprofitable — undesirable, that is, if the goal is to maximize the sum of consumers' plus producer's welfare. If innovation is somewhat less costly, as in row 3, it is socially desirable but privately unprofitable. If innovation is less costly still, as in row 4, it will be privately profitable as well as socially desirable.

In this example, market power is at its maximum: there is one supplier and (by construction) no possibility of entry. But complete monopoly power is not always sufficient to support socially desirable R&D. Reliance on market power to provide incentives to invest in R&D is a second-best solution to imperfections in the market for innovation.

*Oligopoly research and development*

Table 10.3 shows that rivalry in innovation can sometimes produce results that monopoly market power does not. It extends line 2 of Table 10.2 from monopoly to independent oligopoly innovation. In the market for innovation, each firm sets up its own R&D project, if it is profitable to do so. If a firm sets up an R&D project, it picks the most profitable R&D intensity, taking the R&D intensities of other firms as given.

The first row of Table 10.3 reproduces the corresponding values from line 2 of Table 10.2. The rows that follow show equilibrium values if there are two, three, four, and five firms, respectively, in the market. As one would expect, the greater the number of firms, the lower is expected firm value (with or without innovation) and the greater is expected consumers' surplus.7

But expected firm value without innovation falls more rapidly as the number of firms increases than expected firm value with R&D. If an

<table>
<thead>
<tr>
<th>n</th>
<th>h</th>
<th>E(disc)</th>
<th>VRD</th>
<th>VST</th>
<th>CSRD</th>
<th>CST</th>
<th>NSWRD</th>
<th>NSWST</th>
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<tr>
<td>1</td>
<td>4.4294</td>
<td>0.2258</td>
<td>5,193.75</td>
<td>9,000.00</td>
<td>6,975.37</td>
<td>4,500.00</td>
<td>12,169.11</td>
<td>13,500.00</td>
</tr>
<tr>
<td>2</td>
<td>4.2288</td>
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<td>21,157.22</td>
<td>19,748.57</td>
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<tr>
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<td>0.0659</td>
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<td>1,575.00</td>
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<td>23,778.98</td>
<td>21,262.50</td>
</tr>
<tr>
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<td>0.0455</td>
<td>995.52</td>
<td>915.45</td>
<td>21,293.52</td>
<td>18,308.97</td>
<td>25,275.61</td>
<td>21,970.76</td>
</tr>
<tr>
<td>5</td>
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<td>0.0337</td>
<td>841.96</td>
<td>596.94</td>
<td>22,103.38</td>
<td>19,400.51</td>
<td>26,313.17</td>
<td>22,385.20</td>
</tr>
</tbody>
</table>

*Notes:* Independent R&D and independent pricing; n is the number of firms; h is equilibrium R&D intensity; subscript RD indicates values if R&D takes place; subscript ST indicates values if R&D does not take place; V = firm value; CS = consumers’ surplus; NSW = net social welfare = nV + CS; intercept = 100; c = 40; c = 25; z(h) = 20,000 + 10h + 100h^2; product differentiation parameter = 0.75; spillover parameter = 0.1; interest rate = 0.1.

250
Public Policies Towards Cooperation

Oligopolist sets up an R&D project, it has a chance of gaining a cost advantage that rivals cannot compete away. If there are four or more firms, expected firm value with innovation is greater than expected firm value without innovation. Product-market rivalry can make innovation privately profitable as well as socially desirable.

Increases in the number of firms have other desirable effects on market performance. In Table 10.2, the expected time to discovery falls as the number of rivals increases: the more firms there are in the market, the more independent R&D projects there are, and the more chances, from a social point of view, that some project will succeed. Consumers’ surplus and net social welfare rise as the number of rivals increases. These are standard results of oligopoly models: the greater the number of firms, the better is static market performance.

By reducing the initial flow of profits, product market rivalry makes it relatively more attractive for firms to invest in the new technology. This is a very Schumpeterian story: firms invest in innovation to escape product market rivalry, and in doing so leave consumers and society better off, even though a monopolist would not find it profitable to invest in innovation. Comparison of Tables 10.2 and 10.3 confirms that industries where (Villard, 1958: 491)

‘competitive oligopoly’ prevails are likely to progress most rapidly. …

The basic point is that progress is likely to be rapid (1) when firms are large enough or few enough to afford and benefit from research and (2) when they are under competitive pressure to innovate-utilize the results of research.

Alternative cooperation regimes

I now compare the implications of alternative product-market cooperation regimes for technological performance. The results reported in Table 10.4 refer to an oligopoly of ten firms, and compare equilibrium outcomes under alternative R&D and product-market cooperation regimes.

Table 10.4 illustrates four cases: no R&D, independent R&D and independent production in the post-innovation market, a complete R&D joint venture (including all firms) with independent production in the post-innovation market, and a complete R&D joint venture with joint profit maximization in the post-innovation market.

The first two lines of Table 10.4 repeat the message of Table 10.3: if there is sufficiently strong product-market rivalry, oligopolists will find even relatively costly innovation to be profitable, in an expected-value sense. Investment in R&D offers each firm a chance at getting a cost advantage over its rivals, an advantage that will allow it to reap greater profits than it can hope for continuing to use the existing technology.
## Table 10.4 Innovation under oligopoly, alternative cooperation regimes

<table>
<thead>
<tr>
<th>R&amp;D</th>
<th>Prod</th>
<th>$h$</th>
<th>$E(\text{disc})$</th>
<th>Firm value</th>
<th>Consumers' surplus</th>
<th>Net social welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Ind</td>
<td></td>
<td>Never</td>
<td>154.65</td>
<td>21,651.65</td>
<td>23,198.19</td>
</tr>
<tr>
<td>Ind</td>
<td>Ind</td>
<td>4.2921</td>
<td>0.0123</td>
<td>542.25</td>
<td>23,657.45</td>
<td>29,079.98</td>
</tr>
<tr>
<td>Complete JV</td>
<td>Ind</td>
<td>4.3829</td>
<td>0.2281</td>
<td>-635.92</td>
<td>33,559.02</td>
<td>27,199.78</td>
</tr>
<tr>
<td>Complete JV</td>
<td>Joint</td>
<td>4.5550</td>
<td>0.2195</td>
<td>902.52</td>
<td>9,342.81</td>
<td>18,368.00</td>
</tr>
</tbody>
</table>

Notes: Column 1 indicates the nature of R&D competition, column 2 indicates the nature of product market competition; ten firms; $h$ is equilibrium R&D intensity; subscript RD indicates values if R&D takes place; subscript ST indicates values if R&D does not take place; $V = \text{firm value}$; $CS = \text{consumers'} surplus$; $\text{NSW = net social welfare} = nV + CS$; intercept = 100; $c_1 = 40$; $c_2 = 25$; $z(h) = 20000 + 10h + 1000h^2$; product differentiation parameter = 0.75; spillover parameter = 0.1; interest rate = 0.1.

Joint innovation is not profitable, even though it means that the cost of the development project is divided ten ways, if firms make independent decisions in the post-innovation product market. Product market competition among ten firms is relatively severe; consumers benefit greatly from innovation, but firms are left worse off than they would be without innovation.

A complete R&D joint venture with post-innovation joint-profit maximization is the most profitable option in Table 10.4, but also leaves consumers (and society as a whole) worse off. Product-market cooperation allows firms to collude after discovery of the new technique. This benefits firms, but harms consumers.

One of the principal lessons of transaction cost economics for the organization of economic activity is that under conditions of impacted information, economic agents seeking to maximize their own pay-offs should be expected to engage in misrepresentation when it is in their interest to do so. It can be expected, therefore, that firms will make the representation that joint production in the post-innovation market is necessary to make investment in R&D profitable. Institutional arrangements to govern transactions in the public interest should be structured to control for such misrepresentation.

**Simulation results: recapitulation**

Research and development is a costly and a risky activity. Technological progress is socially desirable if it leaves consumers and producers better off. Cooperation in innovation – R&D joint ventures – spreads the cost of innovation among several firms. This can permit ‘big ticket’ innovation that would otherwise be beyond the budgets of single firms. Cooperation in innovation, however, sacrifices the stimulus that comes from technological
rivalry, the incentive to invest that comes from a hoped-for advantage over rival firms. It also sacrifices the reductions in discovery time that are generated by parallel research paths.

Post-innovation cooperation in production – joint R&D&P – increases the expected profit from innovation. This increases firms’ incentive to invest in R&D, but leaves consumers worse off after discovery. Whether joint production in the post-innovation market is socially desirable depends on a trade-off between consumer welfare and producer welfare. For very costly innovations – so costly that the innovation would not otherwise take place – cooperation in production will be socially beneficial. For modest innovations, post-innovation product-market cooperation harms consumers so much that society is worse off, overall, after innovation.

Market structure, cooperation regimes, and market performance

It would be convenient to be able to report that the economic literature on research and development had reached a consensus on the nature of the relationship between market structure and dynamic market performance. The views summarized in Table 10.5, and discussed below, suggest that this is not yet possible.

Spillovers and appropriability

The rationale behind a patent system is that there is a social interest in establishing property rights in new products and processes as a way of creating private incentives to invest in innovation. This does not mean that complete appropriability of the returns from R&D would be desirable, from a social point of view: this might very well lead to an unwelcome degree of product market power.

The relative speed with which information about research plans and developments circulates in the research community (Mansfield 1985; see also Mansfield et al. 1981) means that the property rights established by the patent system are inherently limited. But there is also evidence that in some markets product differentiation and first-mover advantages allow innovators to collect economic profits over a very long run (Caves et al. 1991). Somewhat more generally (Areeda 1992: 31):

That an invention can be copied … does not always mean the imitation will occur quickly, overcome the inventor’s head start, or bring about perfectly competitive prices depriving innovators of an adequate return.
There is also a large literature on learning by doing and the transfer of knowledge from one party to another; for example (Jorde and Teece 1992: 51):

The transfer of technology among the various activities that constitute innovation is not costless. This is especially true if the know-how to be transferred cannot be easily bundled and shipped out in one lot – which is clearly the case when the development activity must proceed
simultaneously and when the knowledge has a high-tacit component. In these cases, the required transfer of technology cannot be separated from the transfer of personnel ...

The presence of such costs makes it more likely, all else equal, that successful innovators will be able to appropriate a substantial portion of the economic profits that flow from their new products and processes.

Parallel research paths

For advocates of joint R&D, parallel research is wasteful duplication (Jorde and Teece 1992: 52):

Collaborative research also reduces what William Norris, CEO of Control Data Corporation, refers to as ‘shameful and needless duplication of effort’ ... Independent research activities often proceed down identical or near-identical technological paths. This activity is sometimes wasteful and can be minimized if research plans are coordinated. The danger of horizontal coordination, on the other hand, is that it may reduce diversity.... Unquestionably, a system of innovation that converges on just one view of the technological possibilities is likely to close off productive avenues of inquiry.

However, a private enterprise economy, without horizontal coordination and communication, offers no guarantee that the desired level of diversity is achieved at lowest cost.

The closing point is unconvincing. A private enterprise economy, with horizontal coordination and communication, offers no guarantee that the desired level of diversity will be achieved at all (Scott 1993: 6):

much of what might appear to be wasteful duplication may in fact provide the numerous research trials needed to increase the probability of innovation to an appropriate level. ... rivalry may increase desirable diversity in R&D effort.

Parallel research paths contribute to dynamic market efficiency, by ensuring that multiple avenues to reach a new product or process are pursued. In addition, if information has a ‘high-tacit component’ then parallel research efforts are a prerequisite for rivalry in the post-innovation market. Parallel research paths thus contribute to static as well as dynamic market efficiency.
R&D CONSORTIA

User-targeted innovation

It is sometimes asserted that tight vertical relationships are necessary for successful innovation (Jorde and Teece 1992: 49): 8

... innovation does not necessarily begin with research; nor is the process serial. But it does require rapid feedback, mid-course corrections to designs, and redesign. ... R&D personnel must be closely connected to the manufacturing and marketing personnel and to external sources of supply of new components and complementary technologies so that supplier, manufacturer, and customer reactions can be fed back into the design process rapidly.

Hypotheses put forward by Jacob Schmookler (1966, 1972) suggest caution about this claim (Scherer 1982: 225):

Schmookler’s main contention ... was that demand played a leading role in determining both the direction and magnitude of inventive activity. His basic underlying premises were two: (1) That the ability to make inventions is widespread, flexible, and responsive to profit-making opportunities; and (2) That the larger an actual or potential market is, the more inventive activity will be directed towards it ...

Scherer’s own empirical tests, based on a combination of FTC Line of Business data and a broad sample of patents issued to US industrial corporations, confirm the validity of Schmookler’s approach (1982: 236; emphasis added):

at least for capital goods inventions, the main thrust of [Schmookler’s] theory survives. Although weaker than those obtained by Schmookler, the correlations between capital goods patenting and using industry investment are impressive. They persist not only for internal process inventions, but also for capital goods product inventions sold across industry lines. Markets work, both internally and externally, in transmitting demand-pull stimuli.

Schmookler’s demand-pull hypotheses imply that tight vertical links are not a prerequisite for satisfactory technological progress.

R&D joint ventures and static market performance

Jorde and Teece suggest that cooperation in research and development has no implications, in or of itself, for product market performance:

market definition should be tailored to the context of innovation..., and should focus primarily on the market for know-how; specific
product markets become relevant only when commercialization is included within the scope of the cooperative agreement.

Elsewhere (1989: 22), they dismiss the danger of overt collusion in high-technology industries:

The difficulty of assembling all the relevant parties to effectuate an international conspiracy is an insurmountable challenge in industries experiencing rapid technological change.

These views miss much of the modern literature on non-cooperative collusion, the essential theme of which is that without explicit collusion firms can achieve collusive results if for each firm the expected present discounted value of the profit that would be lost by defecting from a tacitly collusive strategy exceeds the expected present discounted value of the income from tacit collusion. It follows from this that the threat to break up an R&D joint venture can be used to induce firms to independently behave in a way that yields collusive results.

If R&D joint ventures are formed non-cooperatively, then they will occur only where firms expect them to be profitable. But if firms expect participation in an R&D joint venture to be profitable, then the threat to break up an R&D joint venture will help sustain tacit collusion on product markets. One can show formally (Martin 1995) that common ownership of an R&D joint venture makes it more likely, all else equal, that non-cooperative collusion will be an equilibrium strategy.

It is difficult to reconcile the claim that tacit or overt collusion is unlikely in high-technology industries with episodes in which R&D cooperation has served as the vehicle for strategic behaviour. An example from the US automobile industry involved strategic delays in the development of emission control technology.9

**Coverage of R&D joint ventures**

A closely related question involves the appropriate horizontal coverage of R&D joint ventures. It is sometimes asserted that nearly complete coverage is essential for efficiency in innovation (Jorde and Teece 1992: 53):

A ‘research joint venture’ may not do enough to overcome appropriability problems, unless many potential competitors are in the joint venture.

Complete R&D joint ventures will generally be less profitable than a system of partial joint ventures (Kamien et al. 1993; Martin 1994). They also raise the possibility of dynamic inefficiency (Scott 1989: 111–12, emphasis added):

the problem that I have illustrated is a general problem that could reasonably be expected to plague many cooperative R&D ventures.
R&D CONSORTIA

The basic conditions create situations in which society would prefer only one firm or an industry-wide cooperative venture if only the single decision-making entity would choose socially optimal values for the number of R&D trials and the periodic expenditure for each. However, the monopolist or industry-wide cooperative venture chooses to underinvest in R&D, and, because of that choice, free-entry non-cooperative rivalry produces an R&D expenditure pattern that results in better R&D performance from society’s standpoint.

One would also have to take into account the possibility that complete or near-complete R&D joint ventures could actually be a mechanism for overt collusion; this does not seem an unreasonable interpretation of the patent pool central to Hartford-Empire Co. et al. v. U.S. 10

The extension of joint R&D to joint R&D&P

One can find claims that separation of production from joint R&D is a source of inefficiencies (Jorde and Teece 1992: 52):

the imposition of a market interface between ‘research’ and ‘commercialization’ activities will most assuredly create a technology transfer challenge, a loss of effectiveness and timeliness, and higher costs.

That Japanese joint R&D does not generally extend to production raises doubts about this position (Scott 1993: 216):

some evidence suggests that Japan’s cooperative ventures are more likely than their U.S. counterparts to develop truly generic research results which the individual firms then incorporate in their proprietary products that benefit not only from the cooperative generic research, but also from the purposive diversification of R&D through the keiretsu groups. The Japanese firms then compete with one another and with foreign firms in the sale of those products that use the generic knowledge that was developed cooperatively.

At a minimum, balanced views suggest that cooperative R&D&P sets up a trade-off between static and dynamic market performance (Jacquemin 1988: 557): 11

a regulation of R&D cooperation excluding any cooperation at the level of the final markets could discourage or destabilize many valuable agreements. However, allowing an extension of cooperation from R&D to manufacturing and distribution encourages collusive behavior which impedes competition and … reduces output.
PUBLIC POLICIES TOWARDS COOPERATION

R&D joint ventures and dynamic market performance

One can find the view that there is no desirable alternative to cooperative research and development (Lee and Lee 1991: 340):

proponents of [joint R&D] emphasize that in today's world of increased competition from abroad and rapidly changing technologies, cooperation is necessary to remain competitive. They point to the advantages of minimizing the costs of developing new technologies, spreading the risks of research and development, reducing unnecessary duplication of research effort, obtaining immediate access to new technologies, new markets and cheap production sources, and making otherwise formidable projects possible.

The view is also held, however, that it is rivalry, not cooperation, that induces private investment in innovation (Scott 1993: 149):

Arguably, Schumpeter's vision, though, is that in an evolutionary context competition and monopoly are part of the same process. Greater competition implies a greater incentive to use divergent research strategies to lessen the anticipated erosion of quasi-rents caused by competition among rival innovations in the postinnovation market.

The position that R&D joint ventures will improve dynamic market performance is not supported by early evidence on the actual consequences of the National Cooperative Research Act of 1984 (Scott 1993: 177):

If the NCRA is to be beneficial, we would expect the act to promote cooperative R&D in those areas where the productivity slump hit hard. To turn around the productivity performance of the economy, the act would stimulate R&D in those industries that were poor performers during the heart of the slump. ... the gains expected from the act would be most likely if the act furthered cooperative R&D in the unconcentrated, fragmented industries, in the lower productivity growth industries, and in industries where the salubrious effects of R&D diversification could not work because the R&D activities in those industries had not been combined with the R&D in other industries. In fact, what we find is quite the opposite: NCRA-protected cooperative R&D is largely in those industries which, during the heart of the productivity slump which laid the groundswell for the NCRA, were already concentrated ..., had higher productivity growth, and whose R&D was already purposively combined with the R&D activities of other industries. Further, there appear to be no unusual appropriability problems in the industries where protected cooperative R&D is occurring.
R&D CONSORTIA

Interfirm cooperation and dynamic market performance: reprise

The most conservative reading that can be given of the economic literature on joint research, development, and production is that there is no compelling reason to think that joint R&D&P will *in general* improve static or dynamic market performance. This is consistent with the simulation results reported above. Joint R&D&P may well be the most effective way, from a social point of view, to obtain very expensive innovations. Unless R&D is extremely costly, however, joint R&D is likely to shut off socially desirable parallel research efforts, reducing the rate of technological progress. It can also facilitate tacit collusion, by providing firms with information about rivals’ views of the market and raising the opportunity cost of vigorous product-market rivalry. These effects are more likely if joint activity covers all or almost all firms in the market. Joint R&D thus has the potential to worsen static *and* dynamic market performance. Except for very costly innovation, the same is true of joint R&D&P.

THE RANGE OF RATIONALES OF POLICY TOWARDS JOINT R&D&P

European Union

*EU policy towards joint R&D&P*

Article 85, paragraph 1, of the Treaty of Rome prohibits interfirm agreements that distort competition in the Common Market.¹² But Article 85, paragraph 3, provides that the European Commission may waive this prohibition for agreements

which [contribute] to improving the production or distribution of goods or to promoting technical or economic progress, while allowing consumers a fair share of the resulting benefit.

For EU competition policy, ‘consumer welfare’ means the welfare of consumers, not the welfare of consumers plus the welfare of producers. A prerequisite for action under Article 85(3) is that the restriction of competition be no more severe than necessary to obtain the identified benefit.

The EC Commission’s early treatment of cooperative research and development under Article 85(3) was permissive, provided that cooperation did not have the effect of blocking post-innovation rivalry (EC Commission 1972: 46):¹³

agreements arrived at for the purpose of undertaking joint research do not generally restrict competition on condition that the enterprises are not restricted as far as their own research activities are concerned, and
that the results of the joint research are made available to all participants in proportion to their participation.

This approach is continued in the Commission's 1984 block exemption for R&D cooperation (EC Commission 1985: 38):\(^{14}\)

The new regulation leaves intact the 1968 Notice on Cooperation between Enterprises, which states that cooperation agreements relating only to R&D normally do not fall under Article 85(1), but extends the favourable treatment to R&D agreements which also provide for joint exploitation of the results.

Joint research and development is thought to be necessary because of market failures of various kinds (EC Commission 1985: 37–8):

in many cases the synergy arising out of cooperation is necessary because it enables the partners to share the financial risks involved and in particular to bring together a wider range of intellectual and mental resources and experience, thus promoting the transfer of technology.

Characteristically, the Commission takes a structural approach to ensure that restraints on competition have strictly limited effects (EC Commission 1985: 39):

(i) where at the time the agreement is entered into, any of the parties are competitors for products which may be improved or replaced by the results of R&D, the exemption applies only if their combined production of such products does not exceed 20% of the market;

(ii) where no two or more of the parties are competitors at the time the agreement is entered into, the exemption applies irrespective of market shares;

(iii) after five years of joint exploitation, the exemption continues to apply, whether the parties were initially competitors or not, only if their combined production for the new product does not exceed 20% of the market.

The Commission's 1993 Notice on cooperative joint ventures\(^{15}\) treats product-market rivalry among independent firms as the normal state of affairs, departures from which are not typically mandated by efficiencies that may flow from R&D cooperation (recital 20):

The economic pressure towards cooperation at the R&D stage does not normally eliminate the possibility of competition between the participating undertakings at the production and distribution stages. The pooling of the production capacity of several undertakings, when it is economically unavoidable, and thus unobjectionable as regards
competition law, does not necessarily imply that these undertakings should also cooperate in the distribution of the products concerned.

The notice takes a realistic view of the impact of a production joint venture on product market performance (recital 22):

The restriction of competition ... between parents and joint ventures typically manifests itself in the division of geographical markets, product markets (especially through specialization) or customers. In such cases the participating undertakings reduce their activity to the role of potential competitors. If they remain active competitors, they will usually be tempted to reduce the intensity of competition by coordinating their business policy, especially as to prices and volume of production or sales or by voluntarily restraining their efforts.

The adverse effect of joint R&D&P is explicitly held to exceed that of joint R&D alone (recital 37):

A research and development joint venture may, in exceptional cases, restrict competition if it excludes individual activity in this area by the parents or if competition by the parents on the market for the resulting products will be restricted. This will normally be the case where the joint venture also assumes the exploitation of the newly developed or improved products or processes.

Once again, the standards outlined by the Commission are structural in nature. If a joint venture's parent firms are very small – aggregate annual turnover less than ECU 200 million and aggregate market shares less than 5 per cent – the joint venture is regarded as having no appreciable effect on competition, and the Article 85(1) prohibition of agreements in restraint of competition does not apply (recital 15). A joint venture that combines research, development, production, and licensing will be exempted under Article 85(3) if its parents' combined market share is less than 20 per cent (recital 48). If the joint venture includes distribution, the standard is more severe: parents' combined market shares must be less than 10 per cent (recital 46).

Joint ventures that do not meet these standards may none the less be exempted, following individual evaluation by the Commission. Once again, the Commission's attitude is more cautious the more closely cooperation approaches the final consumer (recitals 59, 60):

Pure research and development joint ventures which do not fulfil the conditions for group exemption ... can still in general be viewed positively. This type of cooperation normally offers important economic benefits without adversely affecting competition. ... If the joint venture also takes on the manufacture of the jointly researched and developed product, the assessment for the purpose of exemption
PUBLIC POLICIES TOWARDS COOPERATION

must include the principles which apply to production joint ventures. ... Sales joint ventures belong to the category of classic horizontal cartels. ... The Commission will therefore in principle assess sales joint ventures negatively. The Commission takes a positive view however of those cases where joint distribution of the contract products is part of a global cooperation project which merits favourable treatment pursuant to Article 85(3) and for the success of which it is indispensable ... [including] sales joint ventures set up for the joint exploitation of the results of joint R&D, even at the distribution stage.

Structural standards remain important, even for individual exemptions (recital 64):

To assess whether a full-function joint venture raises problems of compatibility with the competition rules or not, an important point of reference is the aggregate market share limit of 10% contained in the group exemption regulations.

The block exemption for cooperative research and development is entirely consistent with the main line of development of EU competition policy, which is one of qualified reliance on the market as a mechanism for resource allocation. Contracts, combinations and concerted practices that restrain trade may be permitted, under Article 85(3) of the Treaty of Rome, if they promote progressiveness, but only if consumers share in the resulting benefits.

The political economy of EU competition policy

The European Commission certainly highlights the economic benefits that flow from an active competition policy (EC Commission 1972: 11; see also 1985: 15):

Competition is the best stimulant of economic activity since it guarantees the widest possible freedom of action to all. An active competition policy ... makes it easier for the supply and demand structures continually to adjust to technological development. ... Through the interplay of decentralized decision-making machinery, competition enables enterprises continuously to improve their efficiency ... competition policy is an essential means for satisfying ... the individual and collective needs of our society.

Despite economists’ advocacy of competition because of its perceived affirmative effects on market performance, however, there is little doubt that EU political support for an active competition policy stems from the perception that, without such a policy, European integration would
ultimately fail (Spaak Report, 1956, p. 53):

Le marché commun ne conduirait pas par lui-même à la répartition la plus rationnelle des activités si les fournisseurs gardaient la possibilité d’approvisionner les utilisateurs à des conditions différentes, en particulier suivant leur nationalité ou le pays de leur résidence. C’est dans ces termes que se pose le problème de la discrimination.

In point of fact, EU competition policy permits various restrictions of competition that are forbidden under US antitrust law. The general conditions required are that the restriction on competition be (at least in principle) temporary, that it be no more severe than necessary to accomplish some approved-of goal, and that consumers eventually benefit.

EU competition policy permits independent firms to agree to specialize in the production of certain lines of products – that is, to agree not to compete in certain lines (EC Commission 1973: 19):

specialization agreements generally contribute to improving the production process … they are particularly suited to strengthening the competitive position of small- and medium-sized firms. The favourable economic effects of specialization lie in the achievement of economies of scale or … in rationalization measures which enable the firms to cut costs by concentrating operations; it can be expected that these measures will lead, in conditions of effective competition, to lower prices and will thus benefit the user.

For similar reasons, and under similar conditions, exclusive purchasing agreements can be permitted (EC Commission 1978: 23–4):

exclusive purchasing agreements can contribute to improving the production and distribution of goods, because they make it possible for the parties to the agreement to plan their production and sales more precisely and over a longer period, to limit the risk of market fluctuation and to lower the cost of production, storage and marketing. And in many cases agreements of this kind give small and medium-sized firms their only opportunity of entering the market and thus increasing competition. However, exemption can only be given where the firms involved do not retain the whole of the benefit. Consumers must be allowed their fair share as well. … These tests are not satisfied if the exclusive arrangements make it more difficult for other firms to sell on the market, and especially if they raise barriers to market entry.

Firms may restrict competition to coordinate the reduction of excess capacity (EC Commission 1983: 43–4):

Structural overcapacity exists where over a prolonged period all the undertakings concerned have been experiencing a significant reduction
in their rates of capacity utilization, a drop in output accompanied by substantial operating losses and where the information available does not indicate that any lasting improvement can be expected in this situation in the medium term.

... the Commission may be able to condone agreements in restraint of competition which relate to a sector as a whole, provided they are aimed solely at achieving a coordinated reduction of overcapacity and do not otherwise restrict free decision-making by the firms involved.

... production can be considered to be improved if the reductions in capacity are likely in the long run to increase profitability and restore competitiveness, and if the coordination of closures helps to mitigate, spread and stagger their impact on employment. ...

... consumers can be considered to enjoy a fair share of the benefits resulting from the agreement if, at the end of the agreement, they can rely on a competitive and economically healthy structure of supply in the Union, without having been deprived during its operation, despite the effects of the capacity cutbacks, of their freedom of choice or the benefit of continued competition between the participating firms ...

And, of course, there is affirmative regional and sectoral aid, by the member states and by the Union's structural funds, that aims to spread the social costs of the working of the market system (EC Commission 1972: 17).18

Even though the operation of market forces is an irreplaceable factor for progress and the most appropriate means of ensuring the best possible distribution of production factors, situations can nevertheless arise when this in itself is not enough to obtain the required results without too much delay and intolerable social tension. When the decisions of the enterprises themselves do not make it possible for the necessary changes to be made at an acceptable cost in social terms, then recourse to relatively short-term and limited intervention is necessary in order to direct such decisions towards an optimal economic and social result. The purpose of such aids must be to re-integrate the sectors and regions benefiting from them within a practicable and efficient system of competition while reducing the social cost of change ...

As its acceptance of these limited and controlled restrictions of competition shows, the European Union's competition policy neither seeks nor relies upon the untrammeled workings of the market system. It begins from the premise that it is in the nature of a market system to adjust slowly to long-run equilibrium, and that the adjustment often generates social costs that can be ameliorated by accepting short-term restrictions on competition.
Restrictions on competition are accepted where they have the effect of maintaining support for the ongoing process of economic integration. Research and development joint ventures, permitted where market structure suggests continued effective competition, fit naturally into this system.

Japan

Encouragement of research and development has been a persistent feature of Japanese industrial policy. As is well known, it is industrial policy that has shaped the characteristically Japanese version of competition policy (Okimoto 1989: 14):

The Japanese government has found ways of reconciling industrial policy with antitrust enforcement. The [J]FTC and MITI have been able to work out differences through negotiations. In Japan’s latecomer system, the commitment to principles of antitrust has not been allowed to shape the content of industrial policy. There are not very many examples that can be cited in which the [J]FTC has ordered MITI to make major changes in industrial policy in order to conform to antitrust statutes. MITI officials try to take antitrust factors into account in formulating industrial policy.

In the early post-war period, controls on foreign exchange were used to channel imports of state-of-the-art equipment towards industries and firms thought to have the greatest prospects for growth. Tax incentives have also been used to induce firms to invest in R&D. Active industrial policy has been used to ensure that cooperative behaviour contributed to public as well as private goals. Joint research associations have been formed with the encouragement and often the funding of the Japanese government. They are not, in general, frameworks within which firms undertake research and development on a cooperative basis (Odagiri 1986: 407):

Most well-known among the research associations is that on very-large-scale integrated circuits (VLSI), which was composed of five computer producers and active from 1976 to 1979. This association, having yielded numerous patents, is said to have established a foundation for the following Japanese success in the semiconductor industry. This well-publicized ‘success’, however, is not typical of research associations. In fact, most of the associations did not have any joint research associations (which the VLSI had), each member firm receiving its share of research funds (partly financed by the government) and carrying out research in its own research institution. Thus they often worked as no more than a channel through which the funds were delivered from the government to the member firms.
The effect of the research association is to ensure rapid dissemination of the results of research and development, ensuring competition in the post-innovation market (Audretsch 1989: 107):

Research undertaken under the auspices of a Japanese research association frequently is not carried out in a joint laboratory where the members engage in cooperative research. Rather, the R&D is usually carried out in each member’s own research laboratory. The resulting information and scientific knowledge is subsequently exchanged in a coordinated manner directed by the research association. This effectively speeds up the process of the diffusion of technological change. Upon completion of the project, the research association is usually dissolved.

The typical form of industrial organization in Japan accentuates this tendency to ensure rivalry in the use of new technologies (Komiya 1993: 52): 19

The industrial organization in [Japan’s mass-production machinery industries] is characterized by a relatively large weight of ‘loose’ vertical integration long-term, continuous and cooperative relationship between parent makers and manufacturers of parts and equipment, and by low weights of both ‘tight’ vertical integration and ‘arm’s-length’ transactions, concerning the production, processing, designing and R&D of parts and manufacturing equipment. These characteristics make possible the long-term, continuous and close cooperation among companies that could not develop through ‘arm’s-length’ transactions, while creating competition through multilateral transactions that could not exist in the ‘tight’ vertical integration.

Under such industrial organization, a new technology or a new product developed by one firm tends to spread to other firms in the industry rapidly through the network of ‘loose’ vertical integration. Thus the structure of Japan’s mass-production type machinery industry is more conducive to the diffusion of new technologies among firms, and therefore to the overall technological process of the industry, than that of its counterparts in other industrialized countries …

Thus cooperative R&D in Japanese industry promotes spillovers, with consequent positive effects on competitiveness.

**United States: a policy pendulum**

According to the 1980 Antitrust Guide Concerning Research Joint Ventures, R&D joint ventures are to be encouraged if they promote research and
development that would not otherwise have taken place (USDJ 1980: 8–9):

If the cost and risk of the research in relation to its potential rewards are such that the participants could not or would not have undertaken the project individually, then the venture will have the effect of increasing rather than decreasing innovation. This may happen, for example, if individual firms lack the resources to finance independent research projects on a reasonably efficient scale or the risks involved in that research are so high that the effort must be shared to make a research project practicable. It may also occur in industries in which the firms are small in size and there is a history of little or no investment in research, so that only joint effort between several firms (or even an industry-wide project) can be expected to produce innovation. If, on the other hand, the joint research replaces existing individual research by the participants or causes those firms to forego research which, in the absence of the joint project, they would have performed individually, the formation of a joint project might well slow the rate of technological progress in the industry, unless the project involves substantial efficiencies.

The 1980 Joint Venture Guidelines embody a cautious approach to restrictions on competition that are ancillary to the functioning of the R&D joint venture (USDJ 1980: 16–17):

collateral restraints on competition that are clearly closely related to achievement of the venture’s essential purposes are ... likely to be legal, while those that are more remotely related to the purposes of the venture are generally of less certain legality, and those whose relationship to the venture’s purposes is tenuous or nonexistent and which are significantly anticompetitive are almost certain to be unlawful.

Examples of closely related collateral restraints include: the obligation to exchange any results from research undertaken previously in the field of the joint research, the duty not to disclose results of the joint research to outside parties until patents are obtained, and the division of particular aspects of the research between the venturers.

... Restraints more remotely related to the legitimate purposes of the joint venture include restrictions on individual development, production and marketing of the inventions resulting from the research. These restrictions imply collaboration extending beyond mere research efforts, resulting in projects which closely approximate joint manufacturing ventures or even mergers. While in some instances these more remote restraints may be reasonably necessary to the success of the joint research, joint research normally does not necessitate joint
development or manufacture. If such extensive collaboration is necessary ..., it should be limited to the results of the joint research and should not encompass other competing products or services marketed by the cooperating firms ...

The National Cooperative Research Act of 1984 was designed to improve productivity by encouraging joint R&D (Scott 1988: 181):

The framers and supporters of the law hoped ... that the promotion of cooperation would increase [the] net social benefit of R&D investment by improving appropriability, lowering costs, lowering risks, decreasing wasteful overbidding (in the sense of too many trials), and reducing actual duplication ...

The NCRA mandates the use of the rule of reason in antitrust cases involving research joint ventures (Scott 1989: 65):

It provided, inter alia, that the behavior of a research consortium, if challenged under the U.S. antitrust laws, would be judged under a rule of reason asking whether the alleged restraints of trade were ancillary to the pursuit of efficiency. For those research ventures notifying the government of their participants and purposes, any subsequent antitrust violation would be assessed single, not treble, damages.

The National Cooperative Production Amendments of 1993 extends rule of reason treatment to production joint ventures. Provided that production facilities are located within the United States, antitrust action against a production joint venture that has been notified to enforcement agencies would involve the possibility of single, rather than treble, damages.

Significantly, the legislation made no provision for a structurally defined "safe harbour", despite the fact that such a provision had appeared in many preliminary proposals. The legislation also declined to assign an exemption power to government agencies (Committee on the Judiciary 1993: 725):

One bill has proposed giving the Federal antitrust agencies the power to exempt joint ventures from all penalties and liabilities under the antitrust laws. ...

The principal difficulty with this proposal lay in its elimination of any threat of private enforcement to ensure that market power is not unreasonably exercised against domestic producers.

The logic of relying on private antitrust enforcement while raising the costs of carrying out a private antitrust action (by mandating the use of the rule of reason) and reducing the possible benefits of a private antitrust action (single rather than treble damages) is not immediately obvious.
CONCLUSION

The economic analysis of technological structure-performance relationships suggests that it is a combination of rivalry and cooperation that delivers the best dynamic market performance. Cooperation in innovation allows firms to spread the cost and risk of investing in uncertain R&D projects. Independent product market behaviour ensures that consumers eventually benefit from successful innovation.

The European Union tolerates strictly limited cooperation among independent firms. Before such cooperation is permitted, it is required that the market structure should support effective product market competition and that consumers will eventually benefit in some demonstrable way.

Japan implements an active industrial policy that aims to promote research and development. By subsidy and tax incentives, government encourages firms to invest in innovation. As a quid pro quo the government establishes institutional frameworks that have the effect of disseminating R&D output and ensuring that there is rivalry in the exploitation of the results of R&D projects.

Both approaches are consistent with what economics has to say about the determinants of dynamic market performance.

The United States has adopted a permissive attitude towards cooperation in research, development, and production, even by large firms and even where market structure gives no assurance of the maintenance of effective competition. In adopting this policy, US policy-makers have ignored substantial evidence that product-market power is not a desirable, or even an effective, tool to promote innovation. It is safe to predict that this policy will increase private profits. It is much less clear that it will improve market performance or benefit consumers.

In the context of US antitrust, which lacks the natural brake on anticompetitive agreements that the drive to integration provides in the European Union, toleration of product-market cooperation will undermine the reliance on rivalry as a resource allocation mechanism that has characterized US policy for a century and which (paradoxically) is in large measure responsible for the Japanese success that motivates suggestions for change. If it is rivalry that promotes desirable market performance, as most industrial economists continue to believe, such toleration will worsen US economic performance.

APPENDIX 10.1 RACING MODELS OF INNOVATION

Monopoly research and development

Consider a situation in which a monopolist uses a technology with constant marginal and average cost $c_1$. The monopolist has the option of setting up an
R&D project to develop a new technology that allows production at unit cost \( c_2 < c_1 \).

Let the random variable \( \tau \) denote the uncertain time of discovery, and suppose that the relationship between research effort \( h \) and the probability of success is exponential,\(^{22}\)

\[
F(t) = \Pr(\tau \leq t) = 1 - e^{-ht}
\]

with corresponding density function

\[
f(t) = F'(t) = he^{-ht}
\]

The probability that discovery has not occurred at time \( t \) is

\[
\Pr(\tau \geq t) = 1 - F(t) = e^{-ht}
\]

The probability of discovery in a short interval of time \( dt \), given that discovery has not occurred at the start of the interval, is then constant,

\[
\frac{F'(t) \, dt}{1 - F(t)} = h \, dt
\]

Integrating by parts, the expected time of completion of a project run at intensity \( h \) is

\[
E(\tau) = \int_0^\infty \tau e^{-ht} \, d\tau = \frac{1}{h}
\]

Let \( z(h) \) denote the cost of an R&D project run at intensity \( h \), with \( z'(h) > 0, \ z''(h) > 0 \). Greater research intensity is therefore more costly but yields a shorter expected time to successful innovation.

If the monopolist undertakes an R&D project, it will select research intensity \( h \) to maximize the present discounted value of its expected income stream:

\[
V_{RD} = \int_{t=0}^\infty e^{-(r+h)t} \left[ \pi_m(c_1) - z(h) + h \frac{\pi_m(c_2)}{r} \right] \, dt
\]

\[
= \frac{\pi_m(c_1) - z(h) + h \frac{\pi_m(c_2)}{r}}{r + h}
\]

The first two terms in the numerator on the right are the monopolist's flow of income while it is using the original technology and operating an R&D project. The third term is the expected present discounted value of monopoly profit using the new technology, from the moment of discovery, weighted by \( h \). The interest rate \( r \) is used to discount future income.
R&D CONSORTIA

The first-order condition for maximization of equation (6) is

\[
V_{RD} = \frac{\pi_m(c_1) - z(h) + \frac{h \pi_m(c_2)}{r}}{r + h} = \frac{\pi_m(c_2)}{r} - z'(h) \quad (7)
\]

Let \( h_m \) denote the solution to (7). For the quadratic cost function \( z(h) = F_R + uh + vh^2 \), which is used for the simulations reported in the text, \( h_m \) is the (positive) solution to the quadratic equation

\[
vh^2 + 2rvh - [\pi_m(c_2) - \pi_m(c_1) - ru + F_R] = 0 \quad (8)
\]

A profit-maximizing monopolist will undertake R&D only if its present discounted value with an R&D project, (6), evaluated for the solution to (7), exceeds its value if it does not undertake R&D,

\[
V_{ST} = \int_{t=0}^{\infty} e^{-rt} \pi_m(c_1) \, dt = \frac{\pi_m(c_1)}{r} \quad (9)
\]

The expected present discounted value of consumers’ surplus if there is R&D is

\[
\int_{t=0}^{\infty} e^{-(r + h_m)t} \left[ CS_m(c_1) + \frac{h_m CS_m(c_2)}{r} \right] dt = \frac{CS_m(c_1) + h_m \frac{CS_m(c_2)}{r}}{r + h_m} \quad (10)
\]

where \( CS_m(c_1) \) is instantaneous consumers’ surplus under monopoly when the old technology is in use and \( CS_m(c_2) \) is instantaneous consumers’ surplus after discovery of the new technology. If there is no R&D, the expected value of consumers’ surplus is

\[
\frac{CS_m(c_1)}{r} \quad (11)
\]

It follows that the change in expected consumer welfare due to research and development under monopoly is

\[
\frac{h_m}{r + h_m} \frac{CS_m(c_2) - CS_m(c_1)}{r} > 0 \quad (12)
\]

A profit-maximizing monopolist will set a lower price when marginal cost is lower; this benefits consumers. If R&D is privately profitable for a monopolist, it raises social welfare.
Oligopoly R&D

Independent R&D with spillovers, independent post-innovation production

Suppose each firm in an $n$-firm oligopoly carries out a single R&D project. Let $\tau_i$ be the random discovery time of firm $i$, which operates an R&D project of intensity $h_i$ at cost $z(h_i)$, $i = 1, 2, \ldots, n$. To allow for possibility of spillovers in R&D activity, let the distribution function of $\tau_i$ be

$$\Pr(\tau_i \leq t) = 1 - \exp(-g_i t)$$  \hspace{1cm} (13)$$

where

$$g_i = h_i + \sigma \sum_{j \neq i} h_j$$  \hspace{1cm} (14)$$

The parameter $\sigma$ lies between zero and one and indicates the degree of spillovers in R&D. $\sigma = 0$ implies that a firm benefits only from its own R&D efforts. For $\sigma = 1$, spillovers are complete; a firm benefits as much from other firms’ R&D efforts as from its own.

The probability that no firm has discovered at time $t$ is

$$\prod_{1}^{n} \Pr(\tau_i > t) = \exp\left(-\sum_{1}^{n} g_i t\right)$$  \hspace{1cm} (15)$$

If no firm has discovered at time $t$, firm $i$’s instantaneous pay-off is

$$\pi_n(c_i) - z(h_i)$$  \hspace{1cm} (16)$$

where $\pi_n(c_i)$ is the non-cooperative oligopoly pay-off when only the first technology is known.

The probability density that firm $i$ discovers first in the time interval $dt$ is the product of the probability that it discovers for the first time during the interval and the probability that no other firm has discovered at the start of the interval,

$$g_i \exp(-g_i t) dt \times \exp\left(-\sum_{j \neq i}^{n} g_j t\right) = g_i \exp\left(-\sum_{j=1}^{n} g_j t\right) dt$$  \hspace{1cm} (17)$$

In this case, firm $i$’s value, from the moment of discovery, is

$$\frac{\pi_w}{r}$$  \hspace{1cm} (18)$$

where $\pi_w$ is the instantaneous profit of the firm that wins the exclusive right to control the use of the new technology. $\pi_w$ depends on the nature of

273
product-market competition and on the appropriability regime, and will be discussed below.

The probability density that some other firm discovers first during the time interval \( dt \) is

\[
\left( \sum_{j \neq i} g_j \right) \exp \left( -\sum_{k=1}^{n} g_k t \right) dt
\]

In this case, firm \( i \)'s value, from the moment of discovery, is

\[
\frac{\pi_L}{r}
\]

(20)

If firm \( i \) undertakes an R&D project, its expected present-discounted value is

\[
V_{RD}^i = \frac{\pi_N(c_1) - z(h_i) + \sum_{j \neq i} g_j \pi_L}{r + \sum_{j=1}^{n} g_j}
\]

(21)

Using

\[
\sum_{j \neq i} g_j = (n - 1)\sigma h_i + [1 + (n - 2)\sigma] \sum_{j \neq i} h_j
\]

(22)

and

\[
\sum_{j=1}^{n} g_j = [1 + (n - 1)\sigma] \sum_{j=1}^{n} h_j
\]

(23)

the first-order condition to maximize (21) is

\[
V_{RD}^i = \frac{\pi_N(c_1) - z(h_i) + \frac{\pi_w + (n - 1)\sigma \pi_L}{r} h_i + \frac{\sigma \pi_w + [1 + (n - 2)\sigma] \pi_L}{r} \sum_{j \neq i} h_j}{r + [1 + (n - 1)\sigma] \sum_{j \neq i} h_j}
\]

\[
= \frac{1}{1 + (n - 1)\sigma} \left[ \frac{\pi_w + (n - 1)\sigma \pi_L}{r} - z'(h_i) \right]
\]

(24)

The second equality implicitly defines firm \( i \)'s R&D intensity reaction function.
PUBLIC POLICIES TOWARDS COOPERATION

Partially condense (24) by setting \( h_j = h_{-1} \) for all \( j \neq 1 \), to obtain an expression for the first-order condition that defines firm 1's profit-maximizing R&D level as a function of the equal R&D levels of all other firms:

\[
0 = \frac{\pi_w - \pi_N(c_1) - (n - 1)\sigma[\pi_N(c_1) - \pi_L]}{1 + (n - 1)\sigma} + z(h_1) + h_1z'(h_1) \\
- \frac{rz'(h_1)}{1 + (n - 1)\sigma} + (n - 1)h_{-1}\left[(1 - \sigma)\frac{\pi_w - \pi_L}{r} - z'(h_1)\right]
\]

(25)

In like manner, obtain an expression for the condensed R&D reaction function of all other firms,

\[
0 = \frac{\pi_w - \pi_N(c_1) - (n - 1)\sigma[\pi_N(c_1) - \pi_L]}{1 + (n - 1)\sigma} + z(h_{-1}) + h_{-1}z'(h_{-1}) \\
- \frac{rz'(h_{-1})}{1 + (n - 1)\sigma} + [h_1 + (n - 2)h_{-1}]\left[(1 - \sigma)\frac{\pi_w - \pi_L}{r} - z'(h_1)\right]
\]

(26)

In equilibrium (setting \( h_1 = h_{-1} = h \)), the slope of firm 1's R&D reaction function is

\[
\frac{\partial h_1}{\partial h_{-1}}_{eq} = \frac{(n - 1)h}{nh + \frac{r}{1 + (n - 1)\sigma}} \left[(1 - \sigma)\frac{\pi_w - \pi_L}{r} - z'(h)\right]
\]

(27)

This is positive for \( \sigma \) near zero, and negative for \( \sigma \) near one. The slope of the condensed reaction function of all other firms is

\[
\frac{\partial h_{-1}}{\partial h_1}_{eq} = \frac{(1 - \sigma)\frac{\pi_w - \pi_L}{r} - z'(h_1)}{nh + \frac{r}{1 + (n - 1)\sigma}} z''(h) - (n - 2)\left[(1 - \sigma)\frac{\pi_w - \pi_L}{r} - z'(h)\right]
\]

(28)

Stability requires that the slopes of the resulting functions be less than one in absolute value at equilibrium; see Henriques (1990) and Suzumura (1992). These conditions are met for the simulation results reported in the text.
R&D CONSORTIA

Given the symmetry that characterizes the model, all firms will choose the same R&D level in equilibrium.\textsuperscript{25} Letting $h_i = h$ for all $i$, (24) becomes

$$V^i_{RD} = \frac{\pi_N(c_1) - z(h) + [1 + (n - 1)\sigma] \pi_w + (n - 1)\pi_L}{r + [1 + (n - 1)\sigma]nh} h$$

$$= \frac{1}{1 + (n - 1)\sigma} \left[ \frac{\pi_w + (n - 1)\sigma\pi_L}{r} - z'(h) \right]$$

(29)

Let $h_N$ denote the solution to (29). For a quadratic R&D cost function, $h_N$ is the solution to the quadratic equation

$$(2n - 1)vh^2 + \left[ \frac{2ru}{1 + (n - 1)\sigma} - (n - 1)(1 - \sigma) \frac{\pi_w - \pi_L}{r} + (n - 1)u \right] h$$

$$- \left[ \frac{\pi_w + (n - 1)\sigma\pi_L - ru}{1 + (n - 1)\sigma} - \pi_N(c_1) + F_R \right] = 0$$

(30)

Under oligopoly with independent R&D and independent post-innovation production, expected consumers’ surplus is

$$CS_N(c_1) + [1 + (n - 1)\sigma]nh_N \frac{CS_N[(n - 1)c_1, c_2]}{r}$$

$$r + [1 + (n - 1)\sigma]nh_N$$

(31)

Here $CS_N(c_1)$ is instantaneous consumers’ surplus in non-cooperative equilibrium if all firms produce with unit cost $c_1$; $CS_N[(n - 1)c_1, c_2]$ is instantaneous consumers’ surplus if $n - 1$ firms produce with unit cost $c_1$ and one firm produces with unit cost $c_2$.\textsuperscript{26}

Instantaneous consumers’ surplus without R&D is

$$\frac{CS_N(c_1)}{r}$$

(32)

The change in expected consumers’ surplus with independent R&D and independent production in oligopoly is

$$\frac{1 + (n - 1)\sigma}{r + [1 + (n - 1)\sigma]nh_N} \frac{CS_N[(n - 1)c_1, c_2] - CS_N(c_1)}{r}$$

(33)

Product-market rivalry normally implies that in non-cooperative equilibrium instantaneous consumers’ surplus will rise after innovation;\textsuperscript{27} we expect (33) to be positive.

276
PUBLIC POLICIES TOWARDS COOPERATION

**Complete R&D joint venture, post-innovation rivalry**

If there is a complete R&D joint venture, firms together finance a single R&D project. After innovation, all firms have access to the new technology. Research intensity $h$ is chosen to maximize expected present-discounted firm value,

$$
V_{RD}^{ji} = \pi_N(c_1) - \frac{\pi_N(c_2)}{r + h} - \frac{\pi_N(c_2)}{n} = \frac{\pi_N(c_2)}{r} - \frac{\pi_N(c_2)}{n} - \frac{z(h)}{n}
$$  \hspace{1cm} (34)

The first expression is the definition of firm value; the second equality is the first-order condition that defines the privately optimal R&D level. Let $h_N^i$ denote this value; for a quadratic R&D cost function, $h_N^i$ is the solution to

$$
u h^2 + 2ruh - \{n[\pi_N(c_2) - \pi_N(c_1)] - ru + F_R\} = 0$$  \hspace{1cm} (35)

With a complete R&D joint venture and independent post-innovation decision-making, expected consumers' surplus is

$$
CS_N(c_1) + h_N^i \frac{CS_N(c_2)}{r} \frac{CS_N(c_2)}{r + h_N^i}
$$  \hspace{1cm} (36)

Expected consumers’ surplus without R&D is given by (32). The change in expected consumers’ surplus due to R&D is

$$\frac{h_N^i}{r + h_N^i} \frac{CS_N(c_2) - CS_N(c_1)}{r} \geq 0$$  \hspace{1cm} (37)

**Complete R&D joint venture, post-innovation joint production**

If firms are able to set up a production joint venture after development of the new technology, then a single firm's post-innovation pay-off is its proportional share of monopoly profit, $\pi_m(c_2)/n$, rather than the non-cooperative equilibrium profit $\pi_N(c_2)$. The relevant expressions follow by making the appropriate substitutions in the previous section. Let $h_{jmm}^i$ denote the equilibrium R&D intensity. Expected consumers’ surplus with R&D is

$$
CS_N(c_1) + h_{jmm}^i \frac{CS_{jmm}(c_2)}{r} \frac{CS_{jmm}(c_2)}{r + h_{jmm}^i}
$$  \hspace{1cm} (38)

277
R&D CONSORTIA

Once again, expected consumers’ surplus without R&D is given by (32). The change in expected consumers’ surplus due to R&D is

\[
\frac{h_{j_{\text{res}}}^i}{r + h_{j_{\text{res}}}^i} \left( \frac{CS_{j_{\text{res}}}(c_2) - CS_N(c_1)}{r} \right)
\]

(39)

which is of ambiguous sign. For very great cost savings, consumers can be better off with joint profit maximization in the post-innovation market than with non-cooperative decision-making in the pre-innovation market. But if the cost saving is modest, consumers will be worse off after innovation. The net welfare effect of innovation will then depend on a trade-off between increased economic profit and reduced consumers’ surplus.

**Complete R&D patent pool, post-innovation rivalry**

Each firm carries out its own R&D project; if any firm develops the new technology, all firms have access to its use. R&D intensity \( h_i \) is chosen to maximize

\[
V'_p = \frac{\pi_N(c_1) - \nabla(h_i) + [1 + (n - 1)\sigma] \left( \sum_{j=1}^{n} h_j \right) \frac{\pi_N(c_2)}{r}}{r + [1 + (n - 1)\sigma] \sum_{j=1}^{n} h_j}
\]

\[
= \frac{\pi_N(c_2)}{r} - \frac{\nabla'(h_i)}{1 + (n - 1)\sigma}
\]

(40)

In equilibrium, all firms will choose the same research intensity; (40) becomes

\[
\frac{\pi_N(c_1) - \nabla(h) + [1 + (n - 1)\sigma]n \nabla(h_i) \frac{\pi_N(c_2)}{r}}{r + [1 + (n - 1)\sigma]n \nabla(h_i)} = \frac{\pi_N(c_2)}{r} - \frac{\nabla'(h)}{1 + (n - 1)\sigma}
\]

(41)

Let \( h_N^{pp} \) denote the solution to (41). Evaluated for a quadratic R&D cost function, (41) \( h_N^{pp} \) is the solution to the quadratic equation

\[
(2n - 1)u h^2 + \left[ \frac{2ru}{1 + (n - 1)\sigma} + (n - 1)u \right] h
- \left[ \pi_N(c_2) - \pi_N(c_1) - \frac{ru}{1 + (n - 1)\sigma} + F_R \right] = 0
\]

(42)
PUBLIC POLICIES TOWARDS COOPERATION

Expected consumers’ surplus with R&D is

\[
CS_N(c_1) + \left[1 + (n-1)\sigma \right]nh_{NN}^{pp} \frac{CS_N(c_2)}{r} \frac{CS_N(c_2)}{r + [1 + (n-1)\sigma]nh_{NN}^{pp}}
\]

The change in consumers’ surplus due to research and development is

\[
\frac{1 + (n-1)\sigma}{r + [1 + (n-1)\sigma]nh_{NN}^{pp}} n_{NN}^{pp} \frac{CS_N(c_2) - CS_N(c_1)}{r} \geq 0
\]

One may take the view that \(\sigma\) is a parameter that describes the flow of information in the research community, and that its magnitude will not be affected by the formation of a patent pool.\(^{29}\) Alternatively (Kamien et al. 1992; Choi, 1993) one may argue that the cooperation implied by a patent pool translates into a greater value of \(\sigma\) (perhaps even to 1). The relevant expressions are obtained by altering the value of \(\sigma\) in the preceding expressions.

**Complete R&D patent pool, joint production**

The expression that determines equilibrium R&D intensity \(h_{jjm}^{pp}\) follows from those of the previous section, substituting \(\pi_m(c_2)/n\) for \(\pi_N(c_1)\). Expected consumers’ surplus with R&D is

\[
CS_N(c_1) + \left[1 + (n-1)\sigma \right]nh_{jjm}^{pp} \frac{CS_{jm}(c_2)}{r} \frac{CS_{jm}(c_2)}{r + [1 + (n-1)\sigma]nh_{jjm}^{pp}}
\]

The change in consumers’ surplus due to R&D is

\[
\frac{1 + (n-1)\sigma}{r + [1 + (n-1)\sigma]nh_{jjm}^{pp}} n_{jjm}^{pp} \frac{CS_{jm}(c_2) - CS_N(c_1)}{r}
\]

which is of ambiguous sign and can lead to the same trade-off identified for the case of an R&D joint venture with post-innovation joint production.

**APPENDIX 10.2 INSTANTANEOUS PAY-OFFS**

The general expressions given above can be applied to any model of product market behaviour. In this chapter I have chosen to simulate results assuming that firms set price and produce substitute varieties of a differentiated product. Friedman (1982: 505) regards this case as being of greatest interest. Results are robust to alternative specifications of the nature of product market competition.

279
R&D CONSORTIA

Demand and consumers’ surplus

Let the inverse demand curve for variety 1 be

$$ p_1 = a - [q_1 + \theta(q_2 + \cdots + q_n)] $$

(47)

with corresponding expressions for other varieties. This is a standard model of demand for differentiated products, due among others to Spence (1976). The parameter $\theta$, assumed to lie between zero and one, measures the degree of product differentiation. $\theta = 1$ implies products are perfect substitutes; if $\theta = 0$, demand for one product is completely independent of the outputs of other products.

The inverse demand curves (47) are consistent with the representative consumer utility function

$$ U = m + a \sum_{i=1}^{n} q_i - \frac{1}{2} \left\{ \sum_{i=1}^{n} \left[ q_i^2 + \theta \sum_{j \neq i} q_i q_j \right] \right\} $$

(48)

where $m$ is a numeraire good and the budget constraint is

$$ Y = m + \sum_{i=1}^{n} p_i q_i $$

(49)

Evaluated at the appropriate equilibrium values, this yields an expression for instantaneous utility:

$$ U = Y + \sum_{i=1}^{n} (a - p_i)q_i - \frac{1}{2} \left\{ \sum_{i=1}^{n} \left[ q_i^2 + \theta \sum_{j \neq i} q_i q_j \right] \right\} $$

(50)

The last two terms on the right measure consumers’ surplus from consumption of the differentiated product group.\(^{30}\)

Equilibrium prices

In the pre-innovation market, all firms produce with constant cost $c_1$ per unit. If there is a complete R&D joint venture or a complete patent pool, then in the post-innovation market, all firms produce with cost $c_2$ per unit. To deal with these cases of identical unit costs, consider the more general case, in which unit costs can differ, since this occurs under some cooperation regimes after innovation. Write $c^i$ for the marginal cost of firm $i$ and rewrite the demand curves in terms of deviations from unit cost as

$$ p_i - c^i = a - c^i - \left( q_i + \theta \sum_{j \neq i} q_j \right) $$

(51)
Inverting the system of equations of which (51) is a part yields demand curves of the form\textsuperscript{31}
\[
(1 - \theta)(1 + (n - 1)\theta)q_1 = [1 + (n - 2)\theta]a^1\theta \sum_{j=2}^{n} a^j - \theta \sum_{j=2}^{n} (p_j - a^j) + (p_1 - c^1) + \theta \sum_{j=2}^{n} (p_j - a^j)
\]
writing $a^i = a - c^i$ for notational compactness.

From (48) we obtain an expression for firm 1's instantaneous profit,
\[
(1 - \theta)(1 + (n - 1)\theta)\pi_1 = (p_1 - c^1)\left\{[1 + (n - 2)\theta]a^1\theta \sum_{j=2}^{n} a^j - \theta \sum_{j=2}^{n} (p_j - a^j) + (p_1 - c^1) + \theta \sum_{j=2}^{n} (p_j - a^j)\right\}
\]
(53)

The first-order condition for maximization of (53) gives the equation of firm 1's price reaction function,
\[
2[1 + (n - 2)\theta](p_1 - c^1) - \theta \sum_{j=2}^{n} (p_j - c^j) = [1 + (n - 2)\theta]a^1\theta \sum_{j=2}^{n} a^j
\]
(54)

Note that (54) implies that anywhere along firm 1's price reaction function, and in particular in equilibrium,
\[
q_1 = \frac{1 + (n - 2)\theta}{(1 - \theta)(1 + (n - 1)\theta)} (p_1 - c^1)
\]
(55)
so that firm 1's pay-off satisfies
\[
\pi_1 = \frac{1 + (n - 2)\theta}{(1 - \theta)(1 + (n - 1)\theta)} (p_1 - c^1)^2
\]
(56)

The system of equations of price reaction functions can be written in matrix form as
\[
[[2 + (2n - 3\theta)]I_n - \theta J_n J_n'](P - C) = \{[1 + (n - 1)\theta]I_n - \theta J_n J_n'(aI_n - C)
\]
(57)

where $I_n$ is the identity matrix, $J_n$ a column vector of ones, $P$ a column vector of prices, $C$ a column vector of unit costs, and subscripts indicate
dimension. Inverting the coefficient matrix on the left in (57), equilibrium prices have the form

\[
p_1 - c_1 = \frac{[2 + 3(n-2)\theta + (n^2 - 5n + 5)\theta^2]a_1 - \theta[1 + (n-2)\theta] \sum_{j=2}^{n} a_j}{[2 + (n-3)\theta][2 + (2n-3)\theta]} \tag{58}
\]

In the pre-innovation market, \( c^i = c_1 \forall i \); (58) reduces to

\[
p - c_1 = \frac{1 - \theta}{2 + (n-3)\theta} (a - c_1) \tag{59}
\]

The non-cooperative equilibrium pay-off in the pre-innovation market is obtained from (56). There is a similar expression for equilibrium price if all firms have the right to use the new technology in the post-innovation market.

**Post-innovation, independent production**

In the post-innovation market, the winner of the patent race has an exclusive right to control the use of the new technology. Assume that the winner is able to license use of the new technology to losers, who pay a royalty fee \( c_1 - c_2 \) per unit of output.\(^{32}\) The winner's and losers' pay-offs are

\[
\pi_w = (p_w - c_2)q_w + (n-1)(c_1 - c_2)q_L \tag{60}
\]

and

\[
\pi_L = (p_L - c_1)q_L \tag{61}
\]

respectively. \( p_w \) and \( p_L \) are found by evaluating (58) for the appropriate values of unit cost; equilibrium outputs follow from (55).

**Post-innovation, joint profit maximization**

If there is a complete R&D joint venture or a complete patent pool and firms are able to coordinate decisions after the new technology is discovered, they will set joint-profit maximizing prices in the post-innovation market,

\[
p_{j,\pi m} = c_2 + \frac{1}{2} (a - c_2) \tag{62}
\]

Output per variety is

\[
q_{j,\pi m} = \frac{1 + (n-2)\theta}{(1 - \theta)[1 + (n-1)\theta]} \frac{a - c_2}{2} \tag{63}
\]
NOTES

1 Innovation race models are one of the two leading ways of modelling innovation that appear in the literature; see Loury (1979), Lee and Wilde (1980), Reinganum (1983, 1989) and Martin (1993a, 1994, 1996). The leading alternative model, due to d’Aspremont and Jacquemin (1988, 1990), assumes a deterministic relationship between R&D inputs and R&D output; see also Henriques (1990), Katz and Ordover (1990), Kamien et al. (1992, 1993), and Suzumura (1992). An advantage of the patent race model is that it permits analysis of the impact of market structure and appropriability regimes on the expected time to discovery.

2 Jorde and Teece (1989: note 11) assert that innovation race models apply only if patents ensure appropriability of the profit that flows from successful innovation. This is simply incorrect. There are mechanisms other than the patent system that allow firms to appropriate some of the returns from successful innovation; businessmen are aware of these mechanisms (Levin et al. 1988). In some cases, they can protect economic profits long after patent protection evaporates (Caves et al. 1991). From a strictly modelling point of view, one can allow for imperfect appropriability in specifying the pay-offs to successful innovation; see appendix 10.2.

3 There are substantial transaction costs associated with the negotiation of such licensing agreements; see Levin et al. (1988: 794), Kay (1992). A specification that allows for partial licensing is indicated in appendix 10.2; see also Simpson and Vonortas (1994).

4 The simulation results reported here are generated by a set of BASIC programmes that are available on request from the author.

5 Neither the assumption that varieties are differentiated nor the assumption that firms set price is essential to the results that follow. Results for Bertrand competition and Cournot (quantity-setting) competition with homogeneous products, which are qualitatively similar to those reported here, are available on request from the author.

6 The inverse demand curve is linear \( p = 100 - Q \). Monopoly profit is 900 per time period with unit cost 40, 1,406.25 per time period with unit cost 25.

7 Note that if there are two firms in the market, instead of one, the innovation is socially desirable. With oligopolistic rivalry, the cost-saving innovation is used to produce a greater output, generating larger welfare gains than under monopoly.

8 See also Jorde and Teece (1992: 57)

the NCRA is not sufficiently permissive. The NCRA unwisely precludes joint manufacturing and production of innovative products and processes, which are often necessary to provide the cooperating ventures with significant feedback information to aid in further innovation and product development, and to make the joint activity profitable.

9 United States v. Automobile Manufacturers Association 1969 Trade Cases (CCH) Para 72,907 (C.D. Cal. 1969)(consent decree), modified 1982–3 Trade Cases (CCH) Para 65,088 (C.D.Cal. 1982). I am indebted to William L. Baldwin and John T. Scott for this reference. For those unfamiliar with the fine points of US legal procedures, a consent decree implies that the parties alleged to have violated the law decline to admit that they did so and promise never to do so again.

10 323 U.S. 386 (1945).
11 See also Stockdale (1992: 283):

The [production joint venture] also increases the likelihood of either tacit or explicit collusion among the participants in other downstream product markets and in upstream research markets.

12 For a summary of EC competition policy provisions as of the end of 1989, see EC Commission (1990); more recently Commission Notice regarding restrictions ancillary to concentrations OJ No. C 203/5, 14 August 1990, and Commission Notice concerning the assessment of cooperative joint ventures pursuant to Article 85 of the EEC Treaty OJ No. C 43/2, 16 February 1993. See also Comanor et al. (1990), Goyder (1992), and Geroski (1993).


16 One example is a Commission decision of 23 December 1992 (OJ No. L 20/14 28 January 1993) treating a joint venture between Ford and Volkswagen to produce a multipurpose vehicle in Portugal, with each parent to distribute its own versions of the vehicle. The decision recognized that the exchange of information among the two parents could affect their behaviour in related markets (recital 21), but saw countervailing benefits in the effective entry of two firms into the market (recital 24), installation of state-of-the-art production capacity in the Community (recital 25), and product improvement (recital 26).


18 See Evans and Martin (1991, 1994). These aspects of EC policy are reinforced by the commitment to social and economic cohesion added to the EEC Treaty by the Single European Act.

19 See also Jorde and Teece (1989: 27): ‘Once the technology is mastered, Japanese firms will then often invest in it with the object of becoming the world cost leader. At this stage, strong competition will emerge to complement earlier cooperation’ and (1989: 30): ‘It is important to note that the Japanese have rejected the model of national champions, and seem to promote cooperation among firms that are rivals. The level of cooperation fades, but does not necessarily disappear, as new products approach the point of sale.’

20 And provided also that parties to the production joint venture are US firms or from countries that accord corresponding treatment to US firms that are parties to overseas joint ventures.

21 See, for example, Jorde and Teece (1992: 75–7).

22 This is the distribution function when the time to discovery is a Poisson process; see Freeman (1963).
This assumption is made for simplicity; the results are qualitatively similar if a
firm carries out multiple research projects.

This is without loss of generality, since all firms set the same R&D level in
equilibrium.

One can investigate non-symmetrical equilibria, in which a single firm would
undertake an R&D programme if and only if its expected value with an R&D
programme exceeded its expected value if it did not undertake an R&D
programme but all other firms did. This leads to a model in which, in equili-
brium, some firms undertake R&D, some do not, and a firm's expected value
falls if it changes its R&D decision. The appropriate stability conditions are
analogous to those of d'Aspremont et al. (1983).

This includes the particular cases in which the winning firm licenses the use of
the new technology to losing firms and in which the cost advantage of the new
technology is so great that losing firms shut down in the post-innovation market.

This is the case, for example, with Cournot competition or Bertrand competition.

Once again, this assumption can be relaxed without fundamentally altering the
nature of the results.

This view is supported by evidence that parties to research joint ventures are
often reluctant to share strategic information; see Stockdale (1992: 288–9).

Additional simplifications are possible. Substituting in (50) from the expression
for the inverse demand curves to eliminate \( a - p \), yields

\[
U = Y + \frac{1}{2} \left[ \sum_{i=1}^{a} q_i^2 + \theta \sum_{j \neq i} q_i q_j \right]
\]

(which is valid when evaluated for optimal quantities). Substituting from the
expressions for the demand curves (52) then yields the indirect utility function.

I limit discussion here to the case in which equilibrium demand for all varieties
is positive. The necessary adjustments in the contrary case are straightforward.

A specification that encompasses the one used here is

\[
\pi_w(\alpha) = [p_w(\alpha) - c_2]q_w(\alpha) + a(n - 1)(c_1 - c_2)q_L(\alpha)
\]

where \( a \), lying between zero and one, measures the degree of appropriability.

REFERENCES

Areeda, Phillip (1992) ‘Antitrust law as industrial policy: should judges and juries
make it?’ in Thomas M. Jorde and David J. Teece (eds) Antitrust, Innovation, and

Link and Gregory Tassey (eds) Cooperative Research and Development: The
Publishers.

Economic Perspectives 4, 3, 97–112.

expiration, entry, and competition in the U.S. pharmaceutical industry’,

Choi, Jai Pil (1993) ‘Cooperative R&D with product market competition’,

Comanor, William S., George, K., Jacquemin, A., Jenny, F., Kantzenbach, E.,


286
PUBLIC POLICIES TOWARDS COOPERATION


R&D CONSORTIA


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