ELSEVIER

European Journal of Political Economy
Vol. 11 (1995) 733–741

European Journal of
POLITICAL
ECONOMY

R&D joint ventures and tacit product market collusion

Stephen Martin *

Department of Economics, European University Institute, Florence, Italy

Accepted 13 February 1995

Abstract

It is shown that R&D joint ventures make it more likely that firms will be able to sustain tacit product-market collusion, all else equal.

JEL classification: L13; O32

Keywords: R&D; Joint ventures; Collusion

1. Introduction

A burgeoning literature explores the economic consequences of research and development (R&D) joint ventures for technological progressiveness. [1] The motivation of this literature is the range of failures (among which, large sunk set-up costs, uncertain and difficult to predict outcomes, and imperfect appropriability) that may impede private investment in R&D. For this reason, and quite naturally, its focus has been the potential impact of R&D joint ventures on technological

* Center of Industrial Economics, University of Copenhagen, Studiestraede 6, 1455 Kopenhagen K, Denmark. E-mail: okosm@pc.ibt.dk

[1] See d'Aspremont and Jacquemin (1988), d'Aspremont and Jacquemin (1990), Henriques (1990), Kamien et al. (1992), Suzumura (1992), Martin (1993), Martin (1994a), and Martin (1994b) among others.

SSDI 0176-2680(95)00026-7

performance, on the level of investment in R&D, on the elimination of duplicate investments, on the rate of development of new processes and products, and so on.

There has been a tendency to pass by the possible impacts of R&D joint ventures on *product market* performance. [2] Indeed, it is sometimes asserted that such impacts do not exist. Jorde and Teece, for example, indicate that when competition policy authorities evaluate the impact of R&D cooperation, they should examine primarily the market for innovation, [3] leaving product markets aside (Jorde and Teece, 1992, p. 59):

> 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.

If this position fails, it has important implications for the ongoing debate over public policy toward private cooperation. [4] If R&D cooperation may mitigate failure in the market for innovation and has no particular implications for product market performance, it is straightforward to recommend a benign attitude toward R&D cooperation. But if R&D cooperation may worsen product market performance, then public policy toward R&D cooperation involves the kind of market power versus efficiency trade-off highlighted by Williamson (1968) in another context. It is by no means clear that this trade-off will always balance out in favor of R&D cooperation.

Here I show that R&D joint ventures may have implications for product market performance, even if they do not allow for joint commercialization. The framework of analysis is the game-theoretic approach to noncooperative collusion, which indicates that in the absence of binding contracts, firms will behave collusively only if tacit collusion implies a greater expected present discounted value than non-collusive behavior.

The results can be foreshadowed intuitively. If R&D joint ventures are formed noncooperatively, then they will be set up only where firms expect them to be more profitable than independent R&D activity. But if firms expect participation in an R&D joint venture to be more profitable than independent R&D activity, then the threat to break up an R&D joint venture can form part of a fallback strategy that will sustain tacit collusion on product markets. I will show this formally for duopoly, supposing that firms use a trigger strategy to make noncoop-

[2] Boyer and Jacquemin (1985) have noted a general tendency of the transaction cost literature to emphasize the efficiency over the strategic impacts of alternative organizational forms.

[3] It is not evident that the term 'the market for know-how' is well defined. The work of Schmookler (1966) and Scherer (1982) strongly suggests that innovation is an activity that takes places within and responds to the incentives provided by product markets. The Vision (to use a Schumpeterian term) of an all-encompassing 'market for innovation' that exists independently of product markets has not yet been demonstrated to have a real-world analog.

[4] See Jorde and Teece (1992), Comanor et al. (1994), and the references cited therein.

erative collusion an equilibrium strategy. Qualitatively similar results arise with more than two firms and with less severe enforcement mechanisms.

2. Tacit collusion without R&D

To provide a basis of comparison, I first work out the stability condition for noncooperative collusion under a trigger strategy if the technology is given and R&D does not occur. If Cournot [5] duopolists act independently, the equilibrium present discounted value of each firm is

$$V_C(c_1) = \frac{\pi_C(c_1)}{r}, \tag{1}$$

where $\pi_C(c_1)$ is Cournot equilibrium flow profit when firms product with constant marginal and average cost c_1 per unit and r is the interest rate. If firms tacitly collude and maximize joint profit, then each firm's present discounted value is

$$V_J(c_1) = \frac{\pi_J(c_1)}{r}. \tag{2}$$

If a firm defects from the collusive output path, it gets a flow payoff $\pi_D > \pi_J(c_1)$ as long as defection is not detected. [6] Once defection is detected, the rival reverts to Cournot behavior forever, and the defecting firm's flow payoff is $\pi_C(c_1) < \pi_J(c_1)$ per unit time period.

Let the probability of detection of cheating be exponential,

$$\Pr(\tau \le t) = 1 - e^{-\delta t}, \tag{3}$$

where the random variable τ is the time to detection. The expected time to discovery, after defection occurs, is $1/\delta$. In this case, the expected present discounted value of a firm that defects from the collusive path is

$$V_D = \int_{t=0}^{\infty} e^{-rt}\left[e^{-\delta t}\pi_D + \delta e^{-\delta t} V_C\right] dt = \frac{\pi_D + \delta V_C}{r+\delta}. \tag{4}$$

The first term in brackets under the integral sign is the defecting firm's flow payoff, given that defection has not been detected, times the probability density that defection has not been detected. The second term is the firm's present-discounted value from the time defection is detected, given by (1), times the appropriate probability density.

[5] The assumption of quantity-setting firms is not restrictive. Other forms of product-market competition can be considered by respecifying the expressions for instantaneous payoffs that follow.

[6] If demand is uncertain and firms are unable to directly monitor rivals' outputs, an expansion of output may persist for some time before rivals conclude that defection has occurred; see Stigler (1964) or Green and Porter (1984).

In order for a trigger strategy to sustain noncooperatively collusive behavior, a firm must expect a greater present discounted value from adhering to than from defecting from the collusive output path, assuming other firms adhere to the collusive output path. In the context of the present model, the condition for the stability of noncooperative collusion is

$$\frac{\pi_J(c_1)}{r} \geq \frac{\pi_D + \delta V_C}{r+\delta}. \tag{5}$$

Condition (5) can be rewritten

$$\frac{\delta}{r} \geq \frac{\pi_D - \pi_J(c_1)}{\pi_J(c_1) - \pi_C(c_1)}. \tag{6}$$

This is the Friedman (1971) trigger strategy stability condition, generalized to allow for imperfect ability to detect defections from collusive behavior.

3. Tacit collusion with R&D

I use a standard patent-race model to explore the implications of an R&D joint venture for the sustainability of tacit collusion. [7] Extend the model of the previous section by supposing that there is the possibility of developing a second technology that will allow production at cost $c_2 < c_1$. To develop the new technology requires setting up a research and development project; the first firm to successfully develop the new technology acquires exclusive rights to control its use. The time of discovery, τ, is a random variable. An R&D project run at intensity level h costs $z(h)$, with $z'(h) > 0$ and $z''(h) > 0$, and has expected time to discovery

$$\Pr(\tau \leq t) = 1 - e^{-ht}, \tag{7}$$

where τ is the random time at which the R&D project yields a usable process and h is the intensity of the research and development project. The expected time of completion of a project run at intensity h is $E(\tau) = 1/h$. Greater research intensity is therefore more costly but implies a shorter expected time to successful innovation.

If firms carry out independent R&D projects, the first firm to succeed in innovation obtains a patent that gives it control over the new technology. Let π_W and π_L denote the winner's and the loser's payoffs, per time period, respectively, in the post-innovation market. [8] If firms set up an R&D joint venture, they evenly

[7] For discussions of this model, see Reinganum (1989) or Martin (1993).

[8] π_W and π_L depend on the assumed nature of competition, on the magnitude of the cost saving that results from innovation $(c_1 - c_2)$, on institutional arrangements (whether or not the winner can license use of the new technology to the loser), and on the degree of appropriability in the post-innovation market. I adopt a general formulation here; see Martin (1994a) for more specific versions of the model.

divide the cost of the R&D project in the pre-innovation market and share access to the new technology in the post-innovation market. Post-innovation oligopoly payoffs are $\pi_C(c_2)$ per firm per time period.

I now examine conditions for the stability of noncooperative collusion in duopoly if cooperative R&D is possible. I need to consider payoffs in four cases: independent output decisions and independent R&D decisions (this is the fallback case for the trigger strategy), collusive output decisions without and with joint R&D, and defection from the collusive output path.

3.1. Independent output decisions, independent R&D decisions

If both firms act independently as regards both output and R&D intensity, firm 1's payoff is

$$V_{C,1} = \int_0^\infty e^{-(r+h_1+h_2)t}\left[\pi_C(c_1) - z(h_1) + h_1\frac{\pi_W}{r} + h_2\frac{\pi_L}{r}\right]dt, \tag{8}$$

where h_i is the intensity of firm i's R&D project. [9]

The probability density that neither firm has developed the new technology at time t is proportional to $\exp-(h_1+h_2)t$; in this case, firm 1's rate of return is $\pi_C(c_1) - z(h_1)$ per time period. This explains the first two terms in brackets in (8). The probability density that firm 1 develops the new technology before firm 2 at time t is proportional to $h_1\exp-(h_1+h_2)t$; the present value of firm 1's payoff if this occurs is π_W/r. This explains the third term in brackets in (8). The probability density that firm 2 develops the new technology before firm 1 at time t is proportional to $h_2\exp-(h_1+h_2)t$; the present value of firm 1's payoff if this occurs is π_L/r. This explains the final term in brackets in (8).

Carrying out the integration in (8) gives

$$V_{C,1} = \frac{\pi_C(c_1) - z(h_1) + (h_1\pi_W + h_2\pi_L)/r}{r + h_1 + h_2}. \tag{9}$$

The first-order condition for maximization of (9) is [10]

$$(r+h_1+h_2)\left[\frac{\pi_W}{r} - z'(h_1)\right] - \left[\pi_C(c_1) - z(h_1) + \frac{h_1\pi_W + h_2\pi_L}{r}\right] = 0. \tag{10}$$

Since firms are identical, in equilibrium they will select the same research

[9] In this formulation, there are no knowledge spillovers in the pre-innovation market. This is not essential to the results of the paper (see Martin (1994a) for a patent race model with pre-innovation spillovers).

[10] Although this is not the place for the analysis, (10) implicitly defines firm 1's R&D intensity reaction function, and can be used as the basis for a graphical analysis of R&D competition.

intensity, h_C; substituting in (10) and rearranging terms implies equilibrium firm value

$$V_C = \frac{\pi_C(c_1) - z(h_C) + h_C((\pi_W + \pi_L)/r)}{r + 2h_C} = \frac{\pi_W}{r} - z'(h_C), \qquad (11)$$

where h_C is Cournot equilibrium intensity.

3.2. Tacit pre-innovation collusion

To compute expected value under tacit collusion, it is necessary to specify the nature of competition in the post-innovation market. For simplicity, I suppose Cournot behavior after discovery of the new technology. Qualitatively similar results hold if it is assumed that there is tacit collusion in the post-innovation market.

Let $\pi_J(c_1)$ be firm 1's collusive payoff before discovery, and h_{J1} per-firm equilibrium R&D intensity if there is product-market collusion but independent R&D. Proceeding as in the previous section, with independent R&D but tacit collusion on output in the pre-innovation market, a firm's equilibrium expected value is

$$V_{J1} = \frac{\pi_J(c_1) - z(h_{J1}) + h_{J1}((\pi_W + \pi_L)/r)}{r + 2h_{J1}} \qquad (12)$$

if R&D is carried out independently.

With pre-innovation collusion and an R&D joint venture, firms earn collusive profit before innovation, and divide the cost of the R&D project. The post-innovation market is a Cournot oligopoly in which both firms have access to the new technology. Equilibrium firm value is

$$V_{J2} = \frac{\pi_J(c_1) - z(h_{J2})/2 + h_{J2}(\pi_C(c_2)/r)}{r + h_{J2}}. \qquad (13)$$

3.3. Defection payoffs

In evaluating the payoff to defection from the collusive output path, I suppose that if a firm alters its R&D intensity from the equilibrium value, detection is immediate. Even with independent R&D, information about R&D activities spreads quickly throughout an industry (Mansfield, 1985; Levin et al., 1988). Then, if a firm defects, it will do so by altering output but not research intensity.

If firms carry out independent R&D projects, the expected present discounted value of a defecting firm is

$$V_{D1} = \int_{t=0}^{\infty} e^{-rt}\left\{e^{-\delta t}\left[\pi_D - z(h_{J1}) + h_{J1}\frac{\pi_W + \pi_L}{r}\right]e^{-2h_{J1}t} + \delta e^{-\delta t}V_C\right\}dt$$
$$= \frac{\pi_D - z(h_{J1}) + h_{J1}((\pi_W + \pi_L)/r)}{r + 2h_{J1} + \delta} + \frac{\delta}{r+\delta}V_C \tag{14}$$

(where V_C is given by (11)).

The probability density that output defection is undetected before discovery of the new technology is proportional to $\exp - \delta t$; the corresponding income/value stream appears in the term in brackets in (14). The probability density that output defection is detected before discovery is proportional to $\delta \exp - \delta t$. In this event, the expected best-reply value of the firm from the moment of defection is given by (11).

In like manner, the expected present discounted value of a defecting firm if there is an R&D joint venture is

$$V_{D2} = \frac{\pi_D - z(h_{J2})/2 + h_{J2}(\pi_C(c_2)/r)}{r + h_{J2} + \delta} + \frac{\delta}{r+\delta}V_C. \tag{15}$$

3.4. Conditions for noncooperative collusion

Tacit collusion will be a noncooperative equilibrium strategy if it yields each firm a greater expected value than defection. The stability condition for equilibrium tacit collusion when research and development is carried out independently is that (12) be greater than or equal to (14). This condition can be written

$$V_{J1} \geq \frac{\pi_D - \pi_J(c_1)}{\delta} + \frac{r + 2h_{J1} + \delta}{r+\delta}V_C. \tag{16}$$

The stability condition for equilibrium tacit collusion with an R&D joint venture is that (13) be greater than or equal to (15). This can be written

$$V_{J2} \geq \frac{\pi_D - \pi_J(c_1)}{\delta} + \frac{r + h_{J2} + \delta}{r+\delta}V_C. \tag{17}$$

Noting that $h_{J1} > h_{J2}$, [11] the right-hand side of (16) is greater than the right-hand side of (17). But the left-hand side of (17) is greater than the left-hand

[11] Each firm has a greater incentive to invest in R&D when R&D projects are independent, to reduce the chance that the other firm will innovate first.

side of (16), and greater precisely to the extent that it is profitable, in an expected present discounted value sense, to form an R&D joint venture.

Formation of an R&D joint venture will typically require a variety of sunk investments. Kay (1992), for example, cites the search for a partner and the negotiation of an agreement between parent firms as sources of transaction costs preliminary to the formation a joint venture. In a market system, R&D joint ventures will be formed only if V_{J2} is expected to exceed V_{J1}, even after covering the cost of such sunk investments.

For R&D joint ventures that are voluntarily and noncooperatively formed by profit-maximizing parents, therefore, condition (17) is more likely to be met than condition (16). This means that noncooperative product-market collusion is more likely to be successful under a legal regime that permits cooperative research and development, because the profit expected to flow from joint R&D is an incentive for firms to refrain from independent behavior on output markets.

4. Conclusion

In a market system, common assets, privately held in the expectation of profit, create common interests. If firms voluntarily form an R&D joint venture, that makes it more likely, all else equal, that they will be able to sustain noncooperative product-market collusion. Against the favorable effects on technological performance that are often attributed to cooperative R&D must be set the possible adverse effects of cooperative R&D on product-market performance.

The specific result obtained here refers to R&D joint ventures. It is clearly, however, just one manifestation of a more general phenomenon. If firms voluntarily form an export cartel, that makes it more likely, all else equal, that they will be able to sustain noncooperative collusion on their domestic market. If firms voluntarily set up a wholly-owned subsidiary to serve a regional domestic market that neither serves separately, that makes it more likely, all else equal, that they will be able to sustain a strategy of tacitly collusive behavior in markets that they both serve. [12] Common assets create common interests, and common interests make it more likely that firms will noncooperatively refrain from rivalrous behavior.

References

d'Aspremont, Claude and Alexis Jacquemin, 1988, Cooperative and noncooperative R&D in duopoly with spillovers, American Economic Review 78, no. 5, 1133–1137.

[12] For real-world examples of such parent-subsidiary relationships, see *In re DeLaval-Stork*, Commission Decision of 25 July 1977 or *U.S.* v. *Penn-Olin Chemical Co.* 378 U.S. 158 (1964).

d'Aspremont, Claude and Alexis Jacquemin, 1990, Cooperative and noncooperative R&D in duopoly with spillovers: Erratum, American Economic Review 80, no. 3, 641–642.

Boyer, Marcel and Alexis Jacquemin, 1985, Organizational choices for efficiency and market power, Economics Letters 18, 79–82.

Comanor, William, Akira Goto and Leonard Waverman, eds., 1994, Competition policy in a global economy, (Routledge, London).

Friedman, James W., 1971, A non-cooperative equilibrium for supergames, Review of Economic Studies 38, no. 1, 1–12 (Reprinted in: Andrew F. Daughety, ed., Cournot oligopoly: Characterization and applications, Cambridge University Press, Cambridge, 1988, pp. 142–157).

Green, Edward J. and Robert H. Porter, 1984, Noncooperative collusion under imperfect price information, Econometrica 52, no. 1, 87–100.

Henriques, Irene, 1990, Cooperative and noncooperative R&D in duopoly with spillovers: Comment, American Economic Review 80, no. 3, 638–640.

Jorde, Thomas M. and David J. Teece, 1992, Innovation, cooperation and antitrust, in: Thomas M. Jorde, and David J. Teece, eds., Antitrust, innovation, and competitiveness (Oxford University Press, Oxford).

Kamien, Morton I., Eitan Muller and Israel Zang, 1992, Cooperative joint ventures and R&D cartels, American Economic Review 82, no. 5, 1293–1306.

Kay, Neil, 1992, Collaborative strategies of firms: Theory and evidence, in: Alfredo Del Monte, ed., Recent developments in the theory of industrial organization (University of Michigan Press, Ann Arbor, MI) 201–231.

Levin, R.C., A.K. Klevorick, R.R. Nelson and Sidney G. Winter, 1988, Appropriating the returns from industrial R&D, Brookings Papers on Economic Activity 1988, 783–820.

Mansfield, Edwin, 1985, How rapidly does new industrial technology leak out?, Journal of Industrial Economics 34, no. 2, 217–223.

Martin, Stephen, 1993, Advanced industrial economics (Basil Blackwell, Oxford).

Martin, Stephen, 1994a, Private and social incentives to form R&D joint ventures, Review of Industrial Organization 9, 157–171.

Martin, Stephen, 1994b, Public policies toward cooperation in research and development: The European Union, Japan, the United States, in: William Comanor, Akira Goto and Leonard Waverman, eds., Competition policy in a global economy (Routledge, London).

Reinganum, Jennifer F., 1989, The timing of innovation: research, development, and diffusion, in: Richard Schmalensee and Robert D. Willig, eds., Handbook of industrial organization, Vol. 1 (North-Holland, Amsterdam) 849–908.

Scherer, F.M., 1982, Demand-pull and technological invention: Schmookler revisited, Journal of Industrial Economics 30, no. 3, 225–237.

Schmookler, Jacob, 1966, Invention and economic growth (Harvard University Press, Cambridge, MA).

Stigler, George J., 1964, A theory of oligopoly, Journal of Political Economy 72, no. 1, 44–61 (Reprinted in George J. Stigler, The organization of industry (Richard D. Irwin, Inc., Homewood, IL, 1968, pp. 39–63).

Suzumura, Kotaro, 1992, Cooperative and noncooperative R&D in an oligopoly with spillovers, American Economic Review 82, no.5, 1307–1320.

Williamson, Oliver E., 1968, Economies as an antitrust defense: The welfare tradeoffs, American Economic Review 58, no. 1, 18–36.