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FIRM'S CHOICE OF R&D INTENSITY IN THE PRESENCE OF AGGREGATE INCREASING RETURNS OF SCALE

by

Stefan Fölster

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PRELIMINARY

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ABSTRACT

When firms possess unique R & D assets such as ideas or particular researchers, and there are aggregate increasing returns to scale in R & D, then there can be several Nash equilibria involving different levels of investment in R & D. However when costless communication is possible firms may be able to coordinate a move towards a pareto-preferred equilibrium provided that the communication is credible. It is shown that in some cases when firms do not move to a pareto-preferred equilibrium in spite of communication one firm may have an incentive to purchase R & D assets from other firms to reap the gain from moving to a high R & D-intensity equilibrium.

In the absence of common knowledge however it is not clear whether players will choose strategies that lead to Nash equilibria. Two hypotheses in this case are that communication is much less useful and that the concentration of R & D assets influences players entry decision. These hypotheses are confirmed in a laboratory experiment.

I. INTRODUCTION

When the transistor was first invented in 1948 few firms were willing to invest in the new technology. Apparently, only a massive government intervention stirred firms to the point where they pursued the technology on their own (Schnee, 1978).[1] This claim is supported by the observation that European firms, the equal of American firms in electronics components before the transistor, never recovered from the fact that they were not equally prodded by government support. Since then many firms have earned fortunes in exploiting this technology.

The industry in this example may have been one that exhibited aggregate increasing returns to R & D. In such an industry there can exist several equilibria with higher or lower levels of R & D investment. This paper analyzes the choice of equilibrium and the possibility of non-equilibrium outcomes in such an industry.

Alfred Marshall argued in his "Principles of Economics" that an industry with competitive firms could exhibit a decreasing long run cost curve due to the fact that one firm's production engenders external economies in terms of educating a skilled work force and spreading knowledge gained by "learning by doing". Later the literature on

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1 Government support was provided in the form of direct contracts for R & D and production refinement. This support totalled 66 million dollars between 1955 and 1961. In addition military procurement provided most of the customer base for these pioneer firms.

imperfect competition disposed of this view. It was argued that a monopolist would always usurp such an industry to internalize the external economies. More recently several papers have followed Kenneth Arrow's (1962) lead in showing that a decentralized competitive equilibrium can exist with increasing returns to scale and externalities. For example Romer (1986) constructs a model in which there are increasing returns to knowledge, but the growth of knowledge is limited by decreasing returns to the production of new knowledge. These models are designed to yield a single competitive equilibrium.

In this paper we consider the case where there can be areas of increasing returns to scale in the production of knowledge. It is then possible that there are several competitive equilibria involving different levels of research. This opens the possibility that a profitable technology may be neglected merely due to a coordination problem: If all firms invested simultaneously they might all find it profitable. Yet none is willing to risk investing too early and losing out at the expense of other firms that can enter later and draw on a pool of skilled technicians and an established knowledge base.

One might think that communication between firms easily resolves the problem. Indeed, following the seminal work on games with costless communication by Crawford and Sobel (1982), and applications by Farrell (1987) and Farrell and Saloner (1985), communication can lead to a specific equilibrium that firms will settle on. When firms are perfectly informed costless communication will allow them to settle on the pareto-preferred equilibrium. With private information however the switch to the pareto-preferred equilibrium may not always occur. Farrell and Saloner (1985) examine the question of when firms will switch to a new common standard, making their products compatible. This involves a similar coordination problem to the one analysed here, but there are a few differences. In the standard-switching problem firms have different preferences. Those opposed to the switch will communicate their opposition, but they cannot convincingly communicate to what extent they are opposed.

In the model considered here preferences play no role. Rather it is firms' estimate of the quality of other firms' research capability that determines whether they judge communication to be credible or not, in effect whether a firm that claims that it will start researching will actually do so.

The result that communication promotes coordination requires common knowledge about parameters that determine the pay-off of other players - as well as about the rationality of other players. In the absence of such common knowledge any decision is "rationalizable" in the sense of Bernheim (1984). In particular this means that communication may not be very useful. This result is confirmed in the experiment.

Further, if players make their entry decision as if they assigned a fixed probability of entering to other players then the degree of concentration of R & D opportunities should affect their decision. If a greater variance of the number of entrants reduced the expected value of entering, then greater concentration should lead to fewer entries. This too is confirmed experimentally.

In the experiment subjects were presented a pay-off function depending on the number of entrants. Then they decided whether to enter themselves. The different treatments allowed for communication/no communication, more/less concentration, and common knowledge or its absence.

Section II discusses how firms' profit function can depend on the aggregate industry research level. Section III defines the Nash equilibria. Section IV derives the equilibrium with costless communication. Section V presents the experimental evidence.

II. THE PROFIT FUNCTION

Assume that there exist T unique R & D assets, and firms invest in t of these. These assets can be interpreted as researchers or unique ideas. Further, these assets are assumed to be symmetric in the sense that they yield the same expected return. Then what is the net present value R(t) of investing in an idea - or employing a researcher?

FIGURE 1

In general, R(t) may take any shape. In particular it may fall below zero in certain intervals in between values of t for which $R(t) > 0$, such as shown in figure 1. This kind of profit function requires only two counteracting effects of varying strength. In the following we concentrate first on the fact that the increased competition implied by a greater t shrinks profits, and second that there positive externalities of each firms research. These can consist of increased education and learning, as argued by Marshall, or they can consist of a kind of mutual inspiration. For example, an additional researcher in a field may develop a measuring instrument that greatly enhances the productivity of all other researchers; or he may have an insight that combines usefully with another researcher's results to improve the quality of both firm's products.[2]

A very simple example of such a profit curve can be derived as follows. Assume that households face the following maximization problem where there are different potential goods

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2 One can also describe the inspiration effect as consisting of returns to researcher specialization. For example, the more researchers are active in a field, the more profitable it becomes for one researcher to specialize on devices that raise the productivity of other researchers.
Industrial R & D decision makers often speak of the "acceptance effect", meaning that one firm is more likely to investigate a technology if a rival seems to become interested. This effect may build on quite different mechanisms than the ones used here to justify the inspiration effect. Yet its effect will be similar: Firms may avoid a new technology, each waiting for the other to pick it up first.

all of which enter symmetrically into demand. All households are assumed to have the same utility function.

$$(1)\ U = \quad x_i^b \qquad s.t.\ p \quad x_i = y \qquad \text{where } 0 < b < 1$$

x_i is consumption of the ith good. Each firm produces only one good after researching toward it. We assume that there is only one factor of production with a cost of w per unit and a cost function of $w\ x_i^z$. In addition there is a cost of research toward the product of G(t). The cost of research declines in t, reflecting the complementarity in R & D. The firm then maximizes profit

$$(2)\ V = p\ x_i - w\ x_i^z - G(t) \qquad \text{where } z > 1 \text{ and } f_t < 0$$

Here p is the price of goods which is the same for all goods due to symmetric demand and production.

The first order conditions, which are also assumed sufficient, are for households and firms respectively

$$(3)\ p = y/xt$$
$$p = w\ z\ x^{z-1}$$

From this one can determine equilibrium x and p and the firm's profit function as

$$(4)\ R = y/t - y/zt - G(t)$$

It is apparent in (4) that firm profits may rise or fall in t depending on the slope of G(t) so there can easily be several points where R = 0.

How plausible is a cost curve such as (2)? Some evidence from a recent survey of research managers in large and medium-sized industrial firms sheds some light on this issue.[3] The research managers were asked to choose a few of their own research projects and then to state whether the entry of rivals into the research area adressed by the various projects was expected to raise or reduce the expected value of the projects. The hypothetical rival was described either as a domestic firm (which implies in the case of Sweden firms in the vicinity of the researching firm) or a foreign firm.

Since all of the queried firms were multinationals with the bulk of sales on the world market the assumption is that the entry of a rival implies a similar degree of competition regardless of whether the rival is domestic or foreign. In contrast the external effects of research are presumably much greater for domestic firms.

Table 1 shows crude results, indicating that for a considerable number of projects the entry of a domestic rival may raise the project's expected value while a foreign

3 This survey was conducted under the auspices of the Institute for Industrial and Social Research in Stockholm. 26 research managers were interviewed and queried specifically about a total of 112 research projects.

competitor reduces it. This is evidence for profit functions of the type shown in figure 1.

TABLE 1

III. NASH EQUILIBRIA AND COORDINATION

As long as no coordination occurs several Nash equilibria are possible. These occur at any value t = e where the following three conditions are fulfilled.

1. R(t) = 0

2. dR/dt < 0

3. No single firm not already researching has enough ideas to raise t to a point where R(t) > 0.

As shown in Figure 1 several equilibria can occur that can be defined as $e_1, e_2, \ldots, e_m$.

Clearly, if firms behave as assumed by the Nash equilibrium, and no coordination occurs, it is possible that new technologies are never explored even though they would have a positive private value to all firms if all firms invested simultaneously.

With perfect information and zero transaction costs some agent may be able to internalize the positive externalities. However with private information a coordination of investment in ideas may not occur because as soon as an agent is expected to succeed in purchasing a number of other business ideas he thereby ensures profitability for the remaining ideas that he did not buy. Then no further agent will sell to the coordinator at a price that makes it worthwhile for the coordinator to complete the congregation of ideas.

To show these points in more detail, suppose one agent starts buying ideas with the aim of collecting at least the m ideas that must be executed simultaneously to ensure profitability. In effect this moves the industry from equilibrium e_1 to e_2. It is common knowledge that someone is purchasing ideas so all individuals hold a probability estimate of the chance that the coordinator succeeds. This estimate may be a function of the number of ideas (i) that the coordinator has already collected, or of other bits of information such as the coordinator's reputation. Assume for simplicity that all individuals arrive at the same estimate of the probability that the number of implemented ideas will eventually exceed the threshold level, Prob(t > m|i), given that the coordinator has already purchased i ideas.

A seller of an idea then sets a sales price equal to his alternative return if he held on to the idea. This is his return discounted by the probability that enough other firms invest to make it worthwhile to commence research:

$$(5) \quad \text{Prob}(t > m|i)\, R(e_1)$$

R is evaluated at the equilibrium e_1 that emerges if at least m firms invest. Since there are many sellers of ideas competition obviates higher sales prices.

The coordinator, who is assumed to have an idea of his own, expects a return to buying all ideas equal to the return to realizing the purchased ideas minus their purchase price as in (5):

$$(6) \quad R(e_1)\ (1 + \sum_{j=1}^{m-1} 1 - Prob(t > m/j)\ )$$

Since the sales price of all individuals' ideas as well as the coordinator's profit are known with certainty, a rational expections equilibrium implies that all individuals can perfectly foresee whether the coordinator will succeed in purchasing m ideas or not. Therefore there are only two possible equilibria: Where $Prob(t > m|i) = 1$ for all i and where $Prob(t > m/i) = 0$ for all i. If the $Prob(t > m/i) = 1$ equilibrium is feasible it will prevail, otherwise the $Prob(t > m/i) = 0$ equilibrium prevails. The latter equilibrium is always feasible. The former equilibrium, where the coordinator succeeds, is feasible only if the coordinator can earn a positive return.

From (6), showing the coordinator's expected profits, it is apparent that the equilibrium with $Prob(t > m|i) = 1$ is feasible only if any transaction or coordination costs are smaller than $R(e_1)$; otherwise the coordinator will not purchase ideas.

Naturally, pure transaction costs may be larger than $R(e_1)$. However, other coordination costs may be more important. In this paper the focus lies on asymmetric information. Suppose that there is a chance $(1 - q)$ that ideas that are bought are worthless. The coordinator has poorer information about the value of ideas than sellers for several reasons: Partly, it may be difficult for him to grasp all details and check information. But more important is that the seller must be unwilling to reveal all details of his idea before a sales contract is signed since revelation means that the buyer can steal the idea at no cost.

At first sight the patent system may appear to solve this problem. In fact it does not. Many business ideas are not patentable. Other ideas may require some R & D investment before they become patentable. Even already patented ideas appear to be poorly protected in practice (see e.g. Mansfield et al., 1981).

The coordinator will not be able to purchase ideas if the money wasted on worthless ideas exceeds his gain. From (6) this means that the equilibrium with $Prob(t > m|i) = 1$ is infeasible if the coordinator's gains from pushing the industry past the inspiration threshold is smaller than the waste arising in the purchase of $m - 1$ functional ideas, that is if

(7) $R(e_1) < (m - 1)(1/q - 1) R(e_1)$

If a single individual cannot purchase ideas, one may ask, why can the firms that have ideas not organize some kind of voluntary coordination or a mutual contract to get all of them investing at once? Again the transaction costs can be high, especially if one attempted to establish binding contracts with all other firms. Probably it is also very difficult to police members to check whether they really are investing at the rate they promised. The next section analyzes the role that mere communication can play in coordination.

IV. SYMMETRIC EQUILIBRIA WITH COSTLESS COMMUNICATION

This section examines the likely equilibrium in the case where no coordinator can profitably purchase ideas, but firms can engage in costless communication.

The seminal work in analysing the role of costless communication is due to Crawford and Sobel (1982) who show how the effectiveness of such communication depends on the degree to which players' preferences coincide. Applications of this idea include Farrell and Saloner (1985) and Farrell (1987). However these applications differ from the current analysis in the pay-off structure of the game and the type of private information which leads to different results.

The game is examined first for the case of two firms, and is generalized to many firms later. Each of two symmetric firms chooses to commence research (in) or not to do so (out). If both enter both win R. If neither enters returns are zero, which may be a normalized value. If one firm enters and the other does not the researching firm loses - L while the other firm gains M. M is assumed to be smaller than either R or L and it may be zero. This can be summarized in a pay-off matrix.

	In	Out
In	(R,R)	(-L,M)
Out	(M,-L)	(0,0)

This game has three Nash equilibria. All of them are symmetric. In one both firms play "in." In the second both firms play "out." The third is a mixed strategy equilibrium where the probability of entry p makes the other player indifferent between "in" and "out."

$$(8) \quad p\,R - (1 - p) = p\,M$$

$$p = \quad L/(R + L - M)$$

In some games the mixed-strategy equilibrium is the only symmetric one which leads to the conclusion that it is the only reasonable equilibrium for identical firms. In the present case however it is less interesting. Note also that it behaves perversely in that a greater benefit of entering R reduces the equilibrium probability of entering.

Now suppose that the game is preceded by costless communication of the following kind. Each firm says "in" or "out". If this results in a Nash equilibrium firms play that equilibrium in the actual game. If it does not result in an equilibrium the communication game is repeated.

In the following we focus on the unique equilibrium that is symmetric so that firms play the same mixed strategy in communication. Suppose that r (s for player 2) is the probability of choosing the communication "in" in the first round of communication. The expected value of repeating the communication is X, with $R \geq X > 0$. Then the expected value of the game for player 1 is

$$(9) \quad V_1 = r \; (s R + (1-s) X) + (1 - r) s X$$

$$= r(sR + X - 2sX) + sX$$

It is clear then that the optimal r is always unity regardless of the s that player 2 plays. Thus there is only a single Nash equilibrium. This is consistent with the findings in Crawford & Sobel (1982) and Farrell and Saloner (1985) that costless communication can usually help players to coordinate activity on pareto preferred equilibria. In fact these authors argue that this is possible because preferences are similar and will occur even when agents have private information. However in the game considered here all firms are interested in getting research started (similar preferences). In spite of that research may not occur when firms have private information.

Suppose, as in the previous section, that each firm suspects that any other firm's idea has a (1 - q) chance of being worthless. Each firm knows with certainty whether its own idea is useful. It learns whether other firms have useful ideas and whether they have invested only when it is too late to invest profitably in the own investment. The problem is now that firms with bad ideas still can earn M if the other firm enters.

Define "in" such that the firm enters if it has a useful idea. Then one can write the pay-off matrix in terms of expected values as follows.

	In	Out
In	(q R + (1 - q)(-L))	-L, q M
Out	q M,-L	0,0

Now if (q R + (1 - q)(-L)) > M then the game has the same pay-off structure as the original game. With costless communication then firms will always choose the in/in equilibrium.

If, however, (q R + (1 - q)(-L)) < M then there is only one Nash equilibrium, namely out/out. We have thus derived a definite criterion for the choice of an equilibrium. The inefficiency arises because in some cases firms will not research even though the other firm actually had a useful idea, and in other cases firms will research even though the other firm did not have a useful idea.

This equilibrium structure carries over to the case of many firms if the equilibrium is defined as follows. If more than m firms say in and the communication is credible, then the in/in equilibrium results. If all firms say "out" or all firms say "in" but their communication is not credible then the out/out equilibrium results. If there is a mix of "in" and "out" then communication is repeated.

We can now redefine R = R(t) as the profit function, M = M(t) as the return to a non-researching firm and F(t,q) as the probability that t firms research a useful idea given that each of T firms has a chance q of having a good idea. Then costless communication leads to the in/in equilibrium if

$$(10) \quad P = \int_0^T (R(t) - M(t))\, f(t,q) \quad dt > 0$$

f is a binomial distribution with $E(t) = q\,T$ and $V(t) = T\,q\,(1 - q)$. However by the central limit theorem it can be approximated by a normal density function provided that T is large. f can then be estimated to have mean $q\,T$ and variance $T\,q\,(1 - q)$.

From this one can derive comparative static results. These results depend on the fact that P changes with the variance of f( ). A rise in the variance v_t can increase or decrease P depending on the shape of R(t). Figure 2 shows two possibilities. With R_2 a decrease in the variance decreases P. With R_1 one achieves the opposite effect.

FIGURE 2

One comparative static result is that the total number of ideas relative to the threshold number is important. For example if 500 out of a thousand ideas must be researched to make research profitable for each firm firms may be more willing tc research than if 5 out of 10 ideas must be researched.

Suppose that each unit t now refers to a ideas, each owned by one firm. Then each unit of t can be seen as sample of a with mean q and variance 1/a q(1 - q) (by the central limit theorem). Then the total variance v_t is 1/a Tq(1 - q). Then it is clear that a rise in "a" raises the variance but leaves the mean unchanged.

Next, return to the possibility of a coordinator. The question is whether a coordinator may purchase ideas in a case where firms do not research.

Suppose the coordinator can purchase all ideas simultaneously. Since firms do not research on their own P must be below zero. The coordinator must then offer a price above zero, and his expected return is

$$(12) \quad \int_0^T (t R - M) f(t) dt$$

The immediate conclusion is that the larger M is the more likely it is that P < 0 and that a coordinator will take over. If there is more than one coordinator then competition between coordinators will drive their return toward zero.[4]

A feature of this model, and most other models incorporating incomplete or asymmetric information, is that there is some common knowledge. For example, firm 1 estimates a chance q that firm 2's idea is feasible. Firm 2 knows that q and it knows that firm 1 knows that firm 2 knows. In many models some probablity distribution is assumed to be common knowledge. This common knowledge makes it possible for one player to calculate others' expected pay-offs for different strategies and thus determine his own optimal action.

Often it is probably more realistic to assume that such common knowledge does not exist. In that case communication may lose its ability to help attain a pareto-preferred Nash equilibrium. In fact this is one of the hypotheses tested experimentally.

In the absence of common knowledge it remains unclear how the decision to enter or not is determined. Communication may now work less well. Each player must now entertain the possibility that other players do not enter because they suspect his estimate of their expected profitability to be low. Since it is now impossible to calculate the opponents expected profits, the

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4 An interesting implication of this model for industrial policy is that social value may be raised in some cases if the government subsidizes research in firms in a way that allows it to check the quality of a firm's research opportunities. If the government proceeds to subsidize these projects it thereby sends a signal about the firm's research opportunites to other firms. This may suffice to motivate other firms to begin researching.

opponent's conjectures remain uncertain in spite of communication.

A heuristic hypothesis is that in the absence of common knowledge players assign a fixed probability of entering to each opponent. While this hypothesis itself cannot be tested it does have testable implications. One is that a greater concentration of R & D assets raises the variance of t. Ignoring q for simplicity, this can be seen as follows. The variance when each firm controls one asset is T p (1 - p). When each firm controls two assets the variance is

$$(11) \quad 0.5\ T\ (p(2 - 2p)^2 + (1 - p)4p^2) = 2\ T\ p\ (1 - p)$$

Similarly it can be shown that the variance of t rises with an increasing number of assets per firm. This idea is pursued in the experiment below.

V. THE EXPERIMENTAL EVIDENCE

The experimental hypotheses are the following:

1. In the absence of common knowledge communication does not raise the probability of entry.
2. In the absence of common knowledge a greater concentration of assets reduces the probability of entry if a greater variance of t reduces E(R).

To test these hypotheses subjects were presented the following game. Either subjects could choose to enter and receive a reward R(t) depending on the number of others that enter; or they could choose not to enter. In that case they received a different reward M(t). The pay-off structure is shown in figure 3.

In the common knowledge treatment subjects were informed that each of a total of 9 projects had 50% percent chance of being workable. The expected values of the pay-offs, assuming that all decide to enter, are in that case E(R) = 6.475 and E(M) = 4.518. Thus it is in the collective interest for all to enter.

The pay-offs consisted of draws in a subsequent lottery with each unit corresponding to one lot out of 100. The lottery prize was SEK 20.

Table 2 shows the 8 different treatments that were applied to 4 games each. In the no-common-knowledge treatment subjects were told that other projects had a chance between 0 and 1 of being workable and that other subjects may have more detailed knowledge about this probability. In fact though, and unknown to subjects, the chance was always 0.5 for all projects. When communication was permitted subjects were allowed to talk for five minutes. The concentration levels were either one project per person implying a total of nine subjects per game, or three projects per person implying three subjects per game.

TABLE 2

The subjects were students at the University of Stockholm from a variety of levels and courses. 9 students at a time played through all 8 treatments. However they were informed of others' responses only after all 8 games were completed. So there were presumably no "repeated game" effects. However there may have been an experience effect. To mitigate this the order in which the 8 games were played was different for each of the 4 selections of 9 students.

RESULTS

The results are shown in Tables 3 and 4. Table 3 shows the percentage of workable projects with which subjects decided to enter. In table 4 X^2 statistics are shown for 12 hypothesis tests. Since there were 4 games in each group there are three degrees of freedom. The critical value of X^2 at the 0.05 significance level is 7.815.

The hypotheses tests indicate that the absence of common knowledge reduces the number of entered projects somewhat, although the difference is not always significant. Communication significantly raises the number of entered projects when there is common knowledge, but not in the absence of common knowledge. In the absence of common knowledge greater concentration reduced the number of entered projects.

TABLES 3 AND 4

CONCLUSION

Technological progress may be prevented by a coordination problem between firms. The experimental evidence presented in this paper suggests that costless communication between firms can solve this coordination problem when firms are well informed about each others' research opportunities. When this information is poor however communication may do little to promote coordination.

In addition the concentration of R & D assets may promote or hinder technological advance depending on whether an increased variance of the number of entries raises or lowers the expected value of entering.

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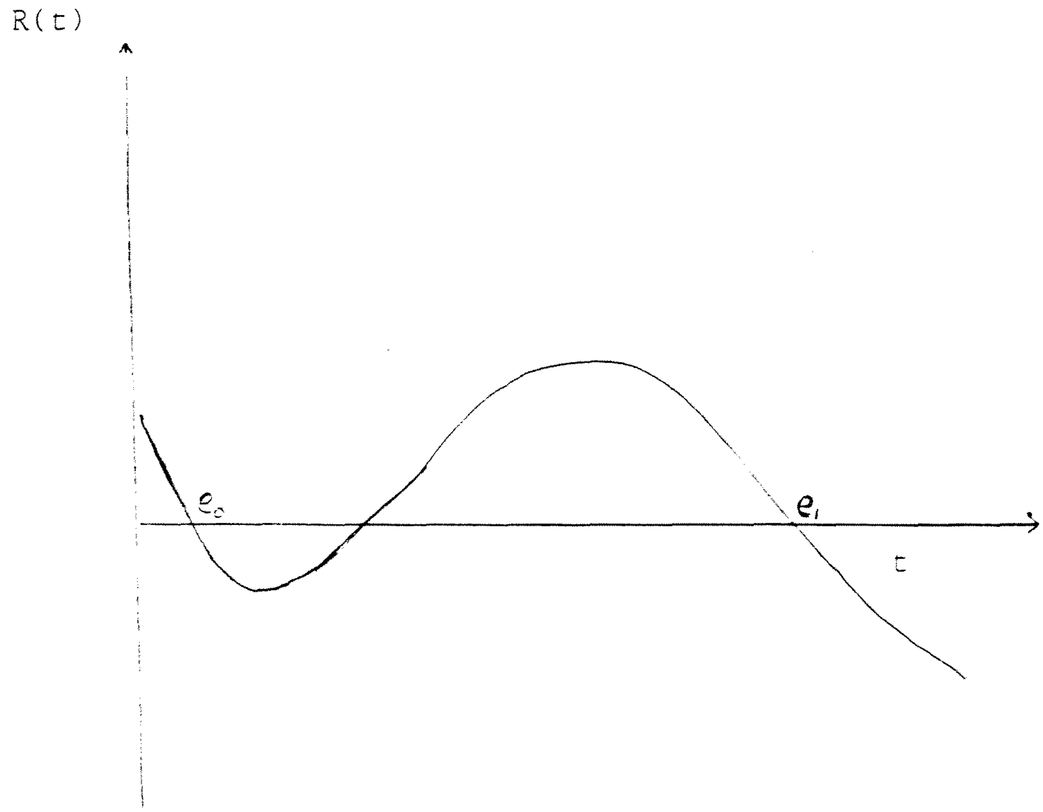

FIGURE 1

EXPECTED PROFIT R(t) PER PROJECT

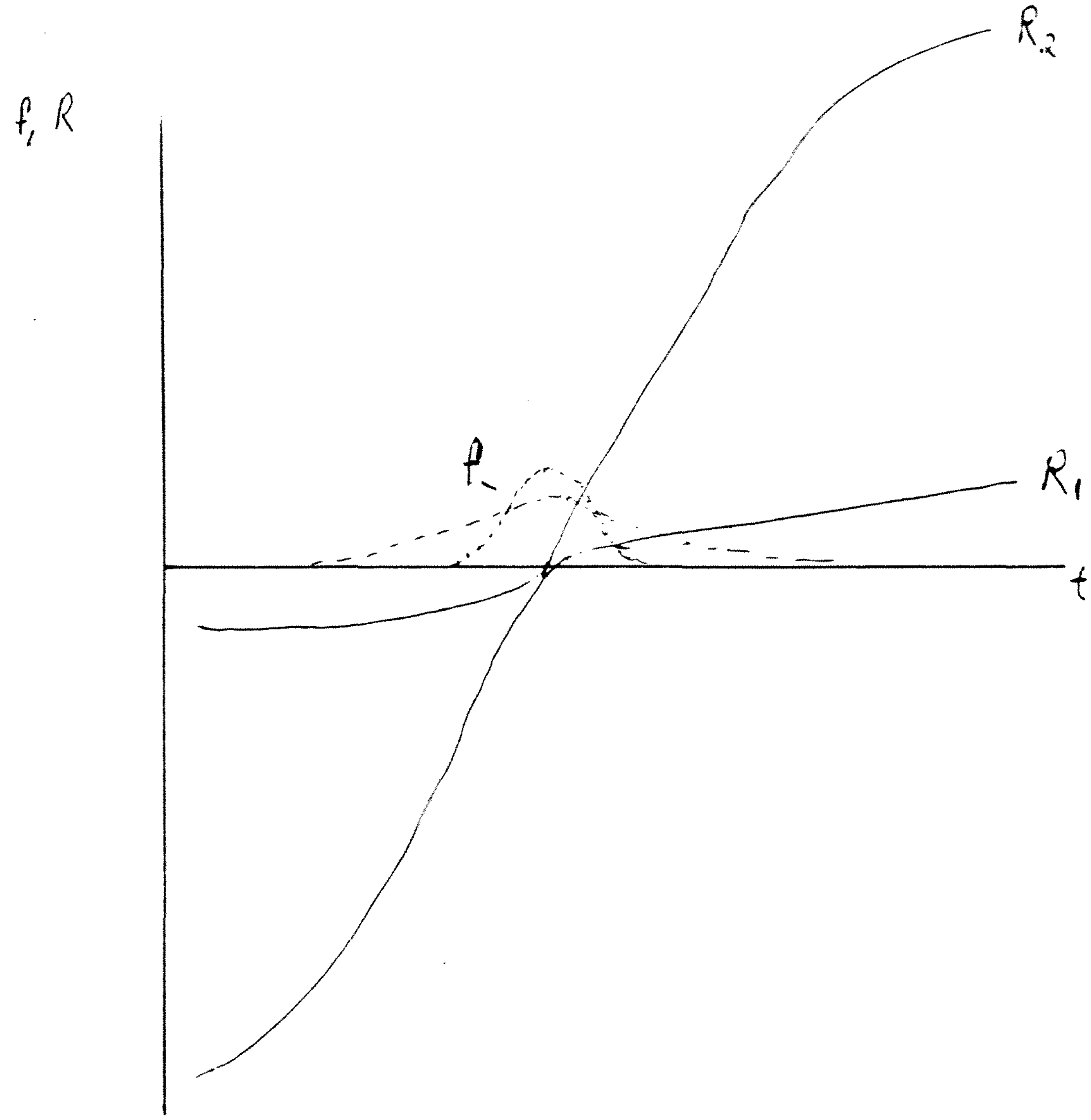

FIGURE 2

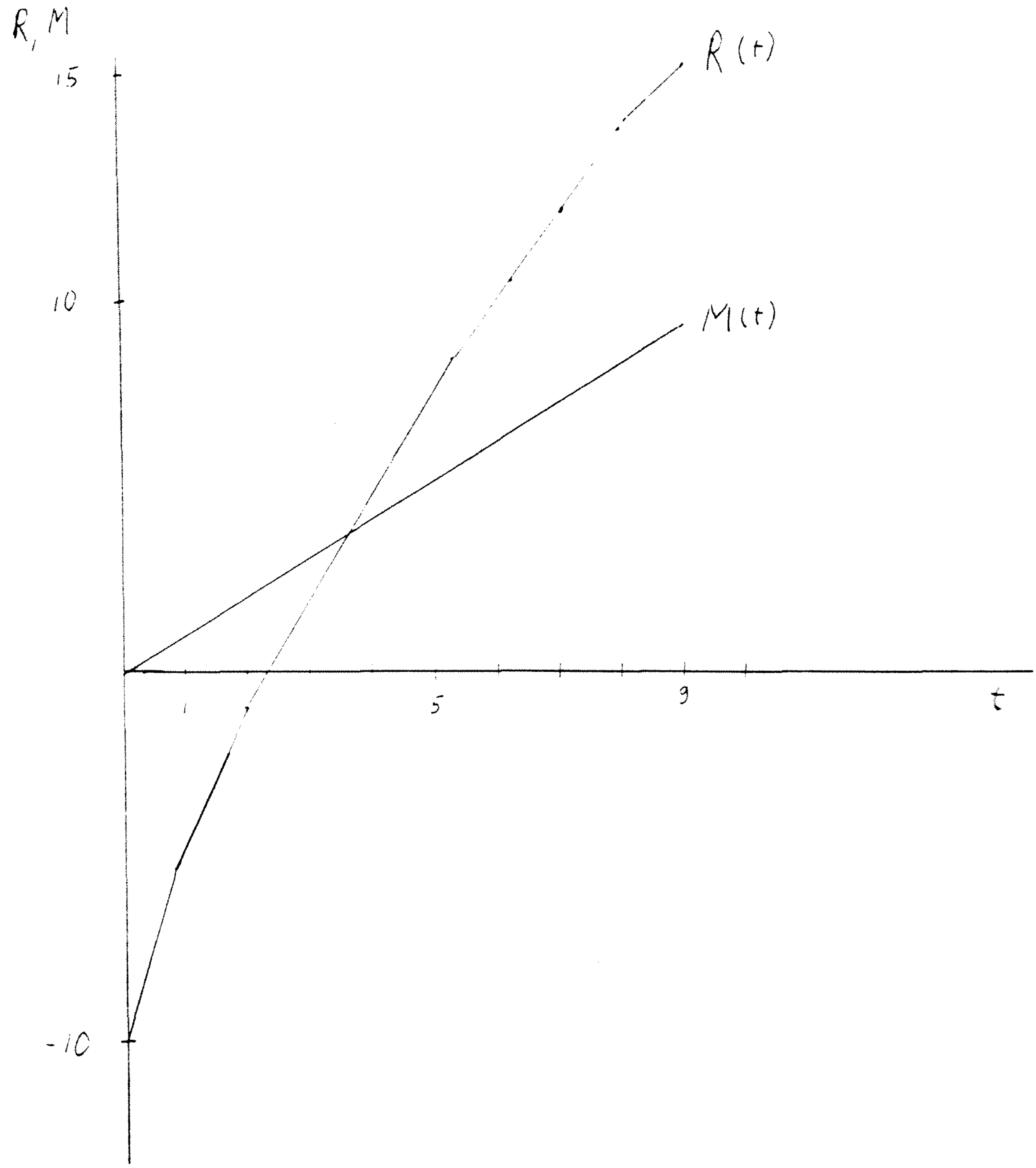

FIGURE 3

PAY-OFF TO ENTERING (R) AND TO NOT ENTERING (M)

		FOREIGN RIVAL	
		RAISES	LOWERS
DOMESTIC RIVAL	RAISES	5	21
	LOWERS	4	76

TABLE 1

NUMBER OF PROJECTS FOR WHICH ENTRY OF A RIVAL CHANGES EXPECTED VALUES

GROUP	INFORMATION	COMMUNICATION	CONCENTRATION
1	CK	No	9
2	CK	No	3
3	CK	Yes	9
4	CK	Yes	3
5	NCK	No	9
6	NCK	No	3
7	NCK	Yes	9
8	NCK	Yes	3

TABLE 2

EXPERIMENTAL TREATMENT
(N)CK: (NO) COMMON KNOWLEDGE, CONCENTRATION
REFERS TO NUMBER OF PERSONS PER GAME

GROUP	MEAN	VARIANCE
1	0.61	0.012
2	0.58	0.008
3	0.98	0.006
4	0.95	0.009
5	0.52	0.010
6	0.40	0.004
7	0.56	0.014
8	0.42	0.018

TABLE 3
ENTERED PROJECTS AS A FRACTION OF
WORKABLE PROJECTS

NULL	ALTERNATIVE	X^2	CRITICAL X^2	NULL REJECTED
COMMUNICATION				
P1=P3	P1=P3	20.42	7.815	NO
P2=P4	P2=P4	17.10	7.815	NO
P5=P7	P5=P7	4.84	7.815	YES
P6=P8	P6=P8	3.21	7.815	YES
CONCENTRATION				
P1=P2	P1=P2	3.93	7.815	YES
P3=P4	P3=P4	5.64	7.815	YES
P5=P6	P5=P6	8.09	7.815	NO
P7=P8	P7=P8	9.44	7.815	NO
COMMON KNOWLEDGE				
P1=P5	P1=P5	6.52	7.815	YES
P2=P6	P2=P6	8.69	7.815	NO
P3=P7	P3=P7	7.89	7.815	NO
P4=P8	P4=P7	5.43	7.815	YES

TABLE 4
TESTING STATISTICAL SIGNIFICANCE
(Px is the proportion of entered projects of all workable projects in the xth group)