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Alternative market arrangements for technology transfer *

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Abstract

With the rapid expansion of markets for telecommunications services and equipment, both national and international, one sees an increasing frequency of alliances in which each of two firms seeks to use the other to complete its portfolio strengths. Often this combination enables firms to achieve the product differentiation that seems to be the key to competitive advantage in modern telecommunications markets. This alliance may take the form of a « joint venture », which in the paper includes as limiting cases a subsidiary wholly owned by one firm, a technology licensing arrangement, and direct exporting. The model of such a venture presented here, although simple, is rich enough to illustrate the influence of four types of factors on the negotiations that set up the venture : demand, costs, risk, and regulatory constraints. We characterize the sets of acceptable and efficient arrangements, under various assumptions about exogeneous factors. The partners must choose among these by some form of bargaining.

Key words : Technology transfer, Firm strategy, Contract, Export, Mathematical model, Risk, Economic analysis.

ACCORDS ET PARTAGE DES RISQUES DU MARCHÉ DE TRANSFERT DE TECHNOLOGIE

Résumé

Avec l'expansion rapide des marchés des services et des équipements de télécommunications, sur le plan national ou international, on assiste au développement d'alliances dans lesquelles chaque firme essaie de compléter son portefeuille de compétences. Ces alliances permettent de mieux réaliser la différenciation des produits qui devient le critère central d'avantage concurrentiel dans les marchés modernes. Une alliance peut prendre la forme d'une entreprise à risques partagés qui, dans l'article, inclut comme cas limites la filiale, les contrats de licence technologique, et l'exportation directe. Le modèle présenté ici, quoique simple, est assez riche pour illustrer l'influence de quatre types de facteurs : la demande, les coûts, le risque et les contraintes réglementaires. Les auteurs caractérisent les ensembles des arrangements acceptables et efficaces avec des hypothèses diverses sur les facteurs exogènes. Les partenaires doivent choisir parmi ceux-ci selon un processus de négociation.

Mots clés : Transfert technologique, Stratégie entreprise, Contrat, Exportation, Modèle mathématique, Risque, Analyse économique.

Contents

I. INTRODUCTION

We start with the observation that firms use various arrangements to sell their products in foreign markets. These include :

— exporting,
— technology licensing,
— joint venture,
— wholly-owned subsidiary,

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in order of increasing overseas capital commitment. We ask : what factors determine which of these modes the firm should choose, and determine the quantitative arrangements within that mode ?

In the formalism we shall develop, exporting, technology licensing, and a wholly-owned subsidiary can all be described as limiting cases of a joint venture. Therefore in what follows we shall always speak of a joint venture.

A joint venture is an alliance of firms (*two* firms, in this paper), often motivated by the desire of each of them to use the other to complete its portfolio of strengths. Typically, one firm has an advantage in technical capability that it wishes to exploit in a new market, while the other has detailed market knowledge, a distribution network, or some other local advantage.

Thus the joint venture becomes a means of technology transfer. The formalism of this paper will be more about contracts than about technology. An effect of the contract that defines a joint venture will be to transfer technology. The technology itself will be implicit in certain parameters of the model to be described below, as we shall point out.

Negotiations between the two firms may deal with a rather long list of parameters ; in our model these include :

— equity shares of the two partners in the joint venture,

— markups by the two partners on intermediate inputs sold by them to the joint venture,

— royalty rates, as a percent of sales, paid by the joint venture to the two partners for use of technology,

— lump-sum payments by the joint venture to the partners.

The cashflows among the two partners and the joint venture are diagrammed in Figure 1. Note that the external arrows determine (to within a random variable — see below) the profits of the whole *enterprise* ; the internal arrows, however, influence the profits of the joint venture.

We shall show that the positions of the partners are actually completely described by two combined parameters, and we shall characterize the sets of acceptable and of Pareto-optimal values of these two parameters under various circumstances. In general, the optimum outcomes are not unique ; the choice among them must be effected by a bargaining process.

The structure of the remainder of this paper is as follows : In Section II we outline factors influencing the contract negotiations between the two partners. In Section III we set up the model and derive our

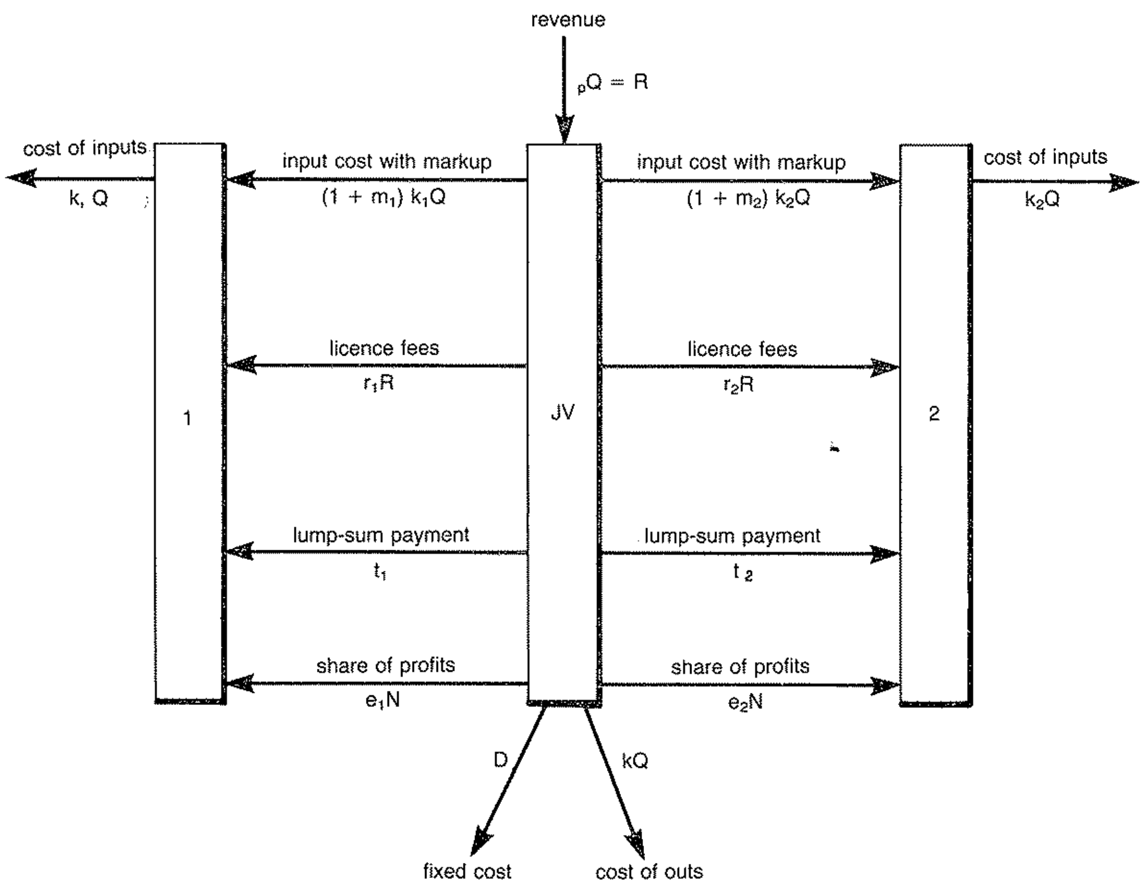

FIG. 1. — Cash flow.

Diagramme financier.

results, including a graphical presentation of the analysis. In Section IV, we say a few words about bargaining. Finally, the Appendix contains a fuller development of the model, including an alternative treatment of risk.

II. FACTORS INFLUENCING NEGOTIATIONS

Many factors may influence the negotiations between the two principals. We have discussed these in some detail elsewhere [Linhart and Radner, 1983] ; here we just outline them. These factors can be grouped under four headings that are, at least in principle, quantifiable, namely : product differentiation, cost, risk, and political constraints.

II.1. Product differentiation.

The uniqueness of the product can be expressed by the price-elasticity of the demand for it. Factors influencing this elasticity are :

— level and uniformity of quality,

— uniqueness of product (as opposed to process) technology (hence lead-time from research to final production) ; we might even include under this heading the ability to market a given type of product,

— compatibility requirements.

II.2. Cost.

Factors that influence the cost of the product at the point of delivery are :

— manufacturing technology,

— factor prices (including the cost of capital),

— scale economies,

— import duties,

— transportation costs,

— exchange rate levels,

— transfer cost of technology.

II.3. Risk.

Risks can be more or less systematic. Some factors are :

— variability of cash-flow stream,

— escape of technology (from targeted markets to a parent firm's competitors),

— expropriation,

— being overtaken by competitor's technology,

— variations in exchange rates.

We also mention that diversification can be used to reduce risk. Risk will be reflected in the model either (i) as the variance of the present worth of the stream of profits to each risk-averse owner of the joint venture, or (ii) as increased cost of capital because of additional undiversifiable risk.

II.4. Political constraints.

— Host government value-added requirements,

— host government local-ownership requirements,

— import quotas,

— the need for local business and government connections (a « soft » political constraint).

Such constraints are represented directly as constraints on the variables and parameters of the model.

III. A MATHEMATICAL MODEL OF A JOINT VENTURE (*)

In this section we describe a mathematical model of some of the aspects of a joint venture. For ease of exposition, we present an unrealistically simple model. (A more realistic model would still be computable but not as transparent.) We have omitted a number of important variables (notably tariffs and other taxes), and we have made very simple assumptions regarding costs, demand, etc. Nevertheless, we can use the model to illustrate several important points concerning the set of acceptable and optimal outcomes of the negotiations about the parameters of the joint venture (share of equity, license fees, markups on intermediate products provided by the partners, and lump sum transfers from the joint venture to the partners). Also, although simple, the model is rich enough to illustrate the influence on the outcome of the negotiation of the four types of factors mentioned above : demand, costs, risk, and political constraints.

We consider a situation in which there are two partners, or rather potential partners, to a joint venture. In the formulas that follow, we shall use the subscript i to denote partner i ($i = 1, 2$).

The model as we present it will appear to be « static », or to cover only one period of time. Alternatively, by interpreting revenues, costs, profits, etc., as *present values*, one makes the model applicable to a multiperiod situation. However (see below) there is only one epoch at which decisions are made.

To simplify the model, we divide all costs into two classes, those that are fixed and those that are proportional to output.

(*) The formulation of this model was stimulated by the model in [Contractor, 1984].

Consider first the following variables (illustrated in Figure 1).

- Q, the output of the joint venture, or an index number of several physical outputs.
- p, the price of the output, or an index number of several prices.
- D, the fixed cost of the joint venture, or the capital investment (*).
- k, the cost to the joint venture, per unit of output, of inputs not supplied by either partner.
- k_i, the cost to partner i of inputs supplied by i to the joint venture (« infeeding »), per unit of output of the joint venture.
- m_i, the markup over cost on inputs supplied by partner i to the joint venture.
- r_i, the license fee paid by the joint venture to partner i, per dollar of joint venture sales (**).
- e_i, the equity share of the joint venture owned by partner i ; e_i is a fraction, and $e_1 + e_2 = 1$.
- t_i, an « up-front » fee paid by the joint venture to partner i (e.g., part of the license fee) ; this payment is independent of the future joint venture revenues.

The price p has been determined outside the model by the two partners, perhaps by a profit-maximization process. Q, however, is assumed to depend on a random variable as well as on p ; that is, demand is uncertain. It is in this way that uncertainty enters the model. Given p, D is assumed to be determined, and known to both partners.

The unit costs k, k_1, k_2 are assumed to be given (note the linearity assumption), and known to both partners.

Before the random demand Q is realized, the partners must agree on the e_i, r_i, t_i and m_i ; Q is then revealed, thus determining profits.

The gross revenue of the joint venture is :

$$R = pQ. \tag{1}$$

The cost of the joint venture is :

$$C = [k + (1 + m_1)\, k_1 + (1 + m_2)\, k_2]\, Q + (r_1 + r_2)\, pQ + (t_1 + t_2) + D. \tag{2}$$

Hence the joint venture's net revenue, or profit, is the difference between (1) and (2), or :

$$\begin{aligned} N &= R - C, \\ &= [p - k - (1 + m_1)\, k_1 - (1 + m_2)\, k_2 - (r_1 + r_2)\, p]\, Q - (t_1 + t_2) - D. \end{aligned} \tag{3}$$

The profit to partner i from the joint venture is made up of three parts : (a) the partner's share of the joint venture's profit, N, (b) the profit on the inputs it sells to the joint venture, and (c) its license and other fees. Hence this profit is :

$$N_i = e_i N + m_i k_i Q + r_i R + t_i\,. \tag{4}$$

We shall suppose, as outlined above, that the investment, output, and pricing plan of the joint venture are given, and shall focus here on the negotiation over the shares (e_i), the (r_i), and (t_i) and the markups (m_i).

Even though the output plan is fixed at the time of the negotiation, the actual future sales are not perfectly predictable, so that Q is a random variable. It follows that each partner's profit, N_i, is also a random variable. Let $\mathrm{E}N_i$ denote the expected value of N_i, and var N_i denote its variance. We suppose that each partner is averse to risk, or neutral towards risk. We represent this by assuming that the objective of partner i is to maximize :

$$u_i = \mathrm{E}N_i - a_i \operatorname{var} N_i\,. \tag{5}$$

Here a_i is a nonnegative parameter that represents partner i's aversion to risk. The number u_i is, in a sense, an expected profit adjusted for risk ; taking some liberty with the standard usage of economic theory we shall call it partner i's *expected utility* (*).

The analysis of the negotiation opportunities is simplified if we suitably rewrite the formula (4) for each partner's profit. Combining (1), (3) and (4) one gets (after some algebra) :

$$N_i = f_i P - A_i\,, \tag{6}$$

where :

$$P = [p - (k + k_1 + k_2)]\, Q, \tag{7}$$

$$\begin{cases} f_1 = e_1 - z, \\ f_2 = e_2 + z, \end{cases} \tag{8a}$$

$$z = \frac{e_1(m_2 k_2 + r_2 p) - e_2(m_1 k_1 + r_1 p)}{p - (k + k_1 + k_2)}, \tag{8b}$$

$$A_1 = e_1 D + (e_1 t_2 - e_2 t_1), \tag{9a}$$

$$A_2 = e_2 D - (e_1 t_2 - e_2 t_1). \tag{9b}$$

Equations (6)-(9) have a simple interpretation. In (7), P is the total « net income » of the entire enterprise, i.e., the income that depends on the quantity sold, after subtracting the variable cost, but before subtracting the amount of the investment, D. According to (6), partner i receives a fraction, f_i, of this total net income, P, less a share, A_i of the fixed investment cost. The fraction f_i differs from the equity share e_i because of the license fees (r_i) and the markups (m_i) ; see (8a) and (8b). The net result of the license fees and the markups is that partner 1 transfers to partner 2 a fraction, z, of the total net income, P. The fraction z may of course be positive, negative, or zero. Similarly, the fixed cost A_i differs from the

(*) One could also include here any fixed costs incurred by the parent firms, e.g., the costs of technology transfer. See footnote 5.

(**) In reality, license fees may be calculated on some other basis ; in such a case r_i is to be interpreted as the equivalent rate per dollar of sales.

(*) See Appendix for a discussion of this point and an alternative approach to risk analysis.

equity share $e_i D$ because of the « up-front » fees, t_1 and t_2. This implies that A_i need not be between 0 and D, even though $e_i D$ is (*). On the other hand, it would be normal for f_i to be between 0 and 1. Since $A_1 + A_2 = D$ and $f_1 + f_2 = 1$, equation (6) shows that *the partners are essentially negotiating over two numbers*, say A_2 *and* f_2, *although they are apparently negotiating over eight numbers*, e_1, e_2, r_1, r_2, m_1, m_2, t_1, *and* t_2.

In equation (6), P is a random variable (since Q is), but D is not. Hence :

$$(10) \qquad \mathrm{E}N_i = f_i \mathrm{E}P - A_i, \qquad \mathrm{var}\ N_i = f_i^2\ \mathrm{var}\ P,$$

and we can rewrite partner i's expected utility in (5) as :

$$(11) \qquad u_i = f_i \mathrm{E}P - A_i - a_i f_i^2\ \mathrm{var}\ P, \quad = f_i \mathrm{E}P - f_i^2 h_i - A_i,$$

where :

$$(12) \qquad h_i \equiv a_i\ \mathrm{var}\ P.$$

Equation (11) enables us to provide a simple characterization of the negotiation opportunities for the two partners, and of the set of optimal negotiation outcomes.

Each partner will have a minimum expected utility from the joint venture that is acceptable. A partner should not accept a negotiation outcome that gives him an expected utility that is less than what he could obtain in the next best alternative use of the resources that would otherwise be used in the joint venture. We shall denote this minimum acceptable expected utility for partner i by u_i^0.

As noted above, since $A_1 + A_2 = D$ and $f_1 + f_2 = 1$, we can represent an outcome of the negotiation by a pair of numbers (f_2, A_2). The set of *acceptable* outcomes is determined by the inequalities :

$$(13) \qquad u_1 \geqslant u_1^0,$$

$$(14) \qquad u_2 \geqslant u_2^0,$$

$$(15) \qquad 0 \leqslant f_2 \leqslant 1,$$

where u_1 and u_2 are determined by (11). The technological situation is expressed by the costs (k, k_1, k_2, D) and the utilities of next-best use (u_1^0, u_2^0).

Furthermore, particular circumstances of the joint venture might impose additional constraints on f_2 and A_2. For example, suppose partner 1 is in the host country, and partner 2 is the foreign partner. If partner 1 has a shortage of capital, then A_1 might be constrained to be no larger than some figure, say 0.6 D.

If the domestic partner has no technology to license, then $r_1 = 0$. If the domestic partner does not provide any inputs to the joint venture (no « infeeding »), then $k_1 = 0$. Note that the last two constraints *together* would imply that $z \geqslant 0$, and hence that $f_2 \geqslant e_2$. However, this is not equivalent to $f_2 \geqslant A_2/D$, since the up-front fees, t_1 and t_2, could be different from zero. Similarly, if the host country requires at least 50 percent domestic equity participation in the joint venture, then $e_2 \leqslant 0.5$. However, this in itself constrains neither f_2 nor A_2, because of the possibility of adjusting the markups and the fees. This illustrates the point that some constraints on the original parameters of the negotiation might not effectively constrain the basic parameters, f_2 and A_2, and hence need not effectively constrain the range of expected utilities that the partners attain.

As mentioned in the Introduction, two of the possible structures, namely exporting and a wholly-owned subsidiary, are limiting cases, obtained by setting $e_1 = k_1 = t_1 = r_1 = 0$. Furthermore, pure technology licensing is a limiting case obtained by setting $e_2 = k_2 = 0$.

Figure 2 illustrates the region of acceptable outcomes for a numerical example in which $u_1^0 = u_2^0 = 0$, and there are no constraints other than (13)-(15). In this and subsequent figures, we have made a change of variables, plotting on the vertical axis $s_2 \equiv A_2/D$ rather than A_2 itself dimensionless. It can be seen from Eqn. (11) that the curves in these figures are just arcs of parabolas. The arrows labelled ① and ② indicate the directions of increasing utility for partners 1 and 2 respectively. Note that it would not be acceptable for either firm to undertake this project separately, since (0, 0) is not in firm 1's acceptable region, and (1, 1) is not in firm 2's acceptable region.

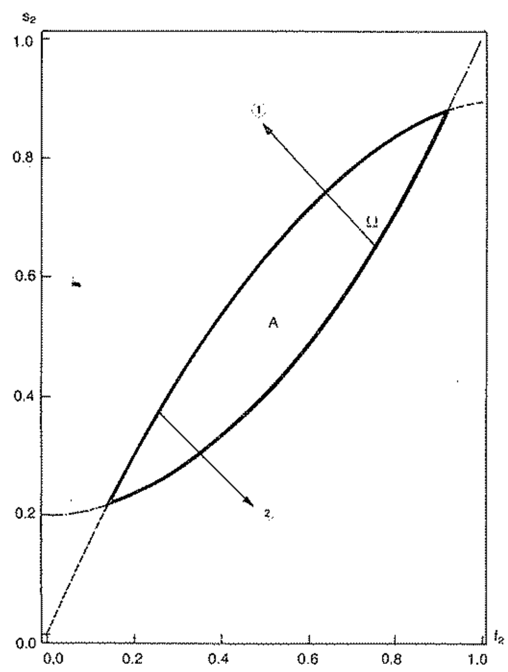

FIG. 2. — Acceptable outcomes without constraints. $D = 10$, $\mathrm{E}P = 16$, $h_1 = 8$, $h_2 = 7$.
—·— $u_1 = 0$, ---- $u_2 = 0$.

Résultats acceptables en l'absence de contraintes.

(*) If D included fixed costs incurred by the parent firms, as in footnote 2, formulas (9a) and (9b) would have to be correspondingly modified. The basic equation (6), however, would remain unchanged.

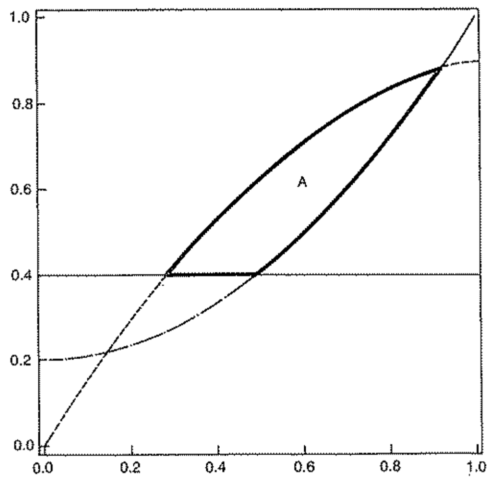

FIG. 3. — Acceptable outcomes,

with constraint on firm 1's capital investment.
$D = 10$, $EP = 16$, $h_1 = 8$, $h_2 = 7$.
—·— $u_1 = 0$, ---- $u_2 = 0$.

Résultats acceptables
avec contrainte sur l'investissement de l'entreprise 1.

Figure 3 is obtained by imposing the further constraint :

$$(16) \qquad s_1 \equiv A_1/D \leqslant .6.$$

In each of the two figures, the region of acceptable outcomes is labelled A. The region A of acceptable outcomes will typically have many outcomes in it (as in the figures), although it is possible for it to have only one outcome (very unusual), or even for it to be empty (see Fig. 4). In the last event, the two partners would not be able to agree on the terms for a joint venture.

Returning to the case of many acceptable outcomes (which we shall henceforth consider), we can further narrow the choice of an outcome by confining our attention to optimal outcomes. An outcome in A is *optimal* if there is no other outcome that is better for one partner without being worse for the other partner. Equivalently, an outcome is optimal if it maximizes each partner's expected utility given the level of the other partner's expected utility.

For the case in which the acceptable region A is determined by (13)-(15), there is a simple characterization of optimal outcomes :

$$(17) \qquad \hat{f}_1 = \frac{h_2}{h_1 + h_2}, \quad \hat{f}_2 = \frac{h_1}{h_1 + h_2},$$

provided that there is an acceptable outcome with this property. (See the Appendix for a proof of this assertion.) The following points should be noted about (17) :

a) There will typically be many optimal outcomes. They will all have the same values of f_1 and f_2, given by (17), but s_1 and s_2 will vary in some interval. This is illustrated in Figure 5, in which the acceptable region is as in Figure 2, and the set of optimal outcomes is the line segment labelled 0. That is, the partners will agree about sharing profit, but bargain about sharing ownership. Within this interval, of course, partner 2 wants s_2 to be lower, and partner 1 wants it to be higher.

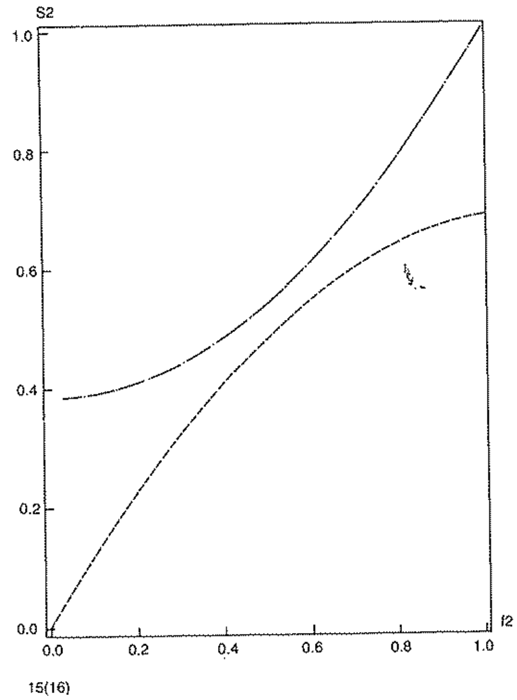

FIG. 4. — No acceptable outcomes.
$D = 13$, $EP = 16$, $h_1 = 8$, $h_2 = 7$.
—·— $u_1 = 0$, ---- $u_2 = 0$.

L'ensemble des résultats acceptables est vide.

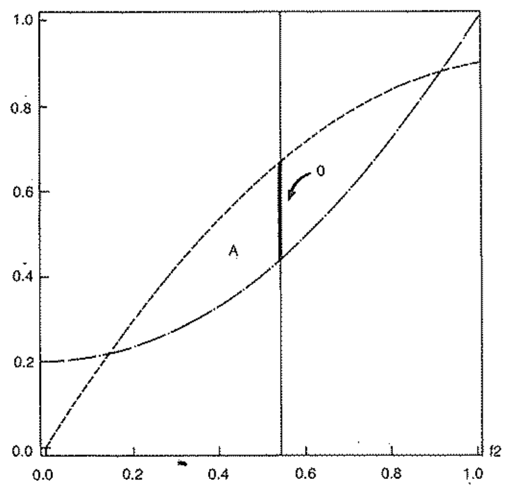

FIG. 5. — Acceptable and optimal outcomes, without constraints.
$D = 10$, $EP = 16$, $h_1 = 8$, $h_2 = 7$.
—·— $u_1 = 0$, ---- $u_2 = 0$.

Résultats acceptables et optimaux en l'absence de contraintes.

b) The optimal values of f_1 and f_2, given by (17), depend on the ratio h_1/h_2 only, and not on the other data of the problem. By (12), this equals the ratio of the partners' risk aversion coefficients, and does not depend on the variance of the net income, P.

c) If there is no outcome that satisfies (17) in the acceptable region, or if there are constraints in addition to (13)-(15), then the set of optimal outcomes may be more complicated to describe, even though easy to calculate. One such case is shown in Figure 6,

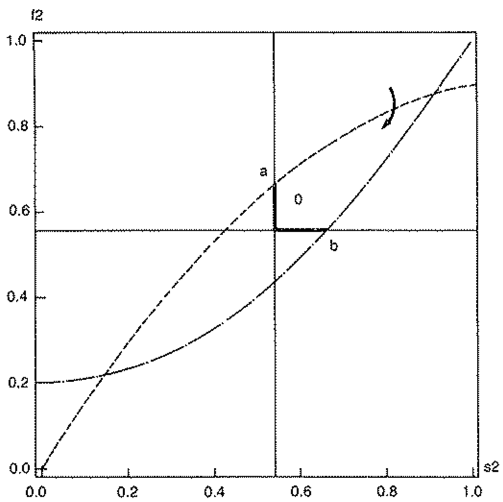

FIG. 6. — Acceptable and optimal outcomes, with constraint on firm 1's investment, case 1. $D = 10$, E$P = 16$, $h_1 = 8$, $h_2 = 7$.
—·— $u_1 = 0$, ---- $u_2 = 0$.

Résultats acceptables et optimaux avec contrainte sur l'investissement de l'entreprise 1 : premier cas.

which is like the previous case, except that s_2 has been constrained to be at least 0.58. It is interesting that the set 0 of optimal outcomes includes not only those optimal outcomes in Figure 5 that are still acceptable, but also some new outcomes on the horizontal boundary of the new acceptable region.

d) The more averse to risk a partner is, the lower will be his optimal value of f_i. This does not mean that he necessarily gets a worse outcome if he is more averse to risk, since a lower value of f_i can be compensated by a lower value of s_i.

e) It follows from point 1 above that financial considerations alone will not typically determine a unique outcome of the negotiation. The actual outcome of the negotiation — even if confined to the set of optimal outcomes — will be influenced by other factors, such as the relative bargaining skills of the partners, or considerations of « fairness ».

f) Even when f_1 and f_2 are determined by (17), it still remains to determine the combination of license fees and markups that achieve those values of the f_i. Of course, if the model has taken everything into account, then the partners should be indifferent between different combinations that produce the same values of the f_i. (In reality, their preferences among these combinations will be determined by considerations that have been simplified out of the present model.)

The Appendix contains a fuller development of the model, including the case in which the two partners may discount future revenues at different rates. This permits us to discuss the situation in which the partners are not strictly averse to risk, but require different rates of return because the parent firms have different risk attributes (as would be suggested by current theories of corporate finance). In this situation, one can take h_i to be zero if the addition of the joint venture does not change the risk attributes of the parent firm i, and/or if the joint venture is small relative to the parent firm. In this case, the set of optimal outcomes is no longer characterized by (17), but will lie on the boundary of the set of acceptable outcomes.

IV. BARGAINING

We have now given a way of focusing attention on the two combinations (of the many contract negotiation parameters) that really matter. We have seen that there are in general many acceptable contracts, and even many optimal acceptable contracts. Some of these are better for one partner, some for the other. A particular outcome will have to be chosen by some process of negotiation or bargaining. This is characteristic of markets with a small number of traders.

The bargaining situation is especially interesting when information is incomplete, which will always be the case. For example, partner 1 may not know k_2, which is the cost to 2 of providing intermediate products to the joint venture. Thus, he will not know the boundary $u_2 = u_2^0$ of partner 2's acceptable utility set. It is even less likely that one partner will know the other's aversion to risk, h_i.

In such a case, it has been shown [Myerson and Satterthwaite, 1953] that no bargaining mechanism (in a wide class) is *efficient* ; that is there is always a possibility that a deal that would have benefitted both partners will fall through (because of too-aggressive bidding). The relative performance of various mechanisms for bilateral bargaining under incomplete information has recently been explored both theoretically and experimentally ; see, for example, Sutton (1986), Leininger *et al.* (1986), Linhart and Radner (1987), Radner and Schotter (1987), and the references cited there.

APPENDIX

In this appendix we present a detailed discussion of the acceptable and optimal outcomes of the joint venture negotiations, under two different hypotheses about how to account for risk, and with different constraints on the set of acceptable outcomes.

Our starting point is equation (11) of Section III :

(A-1) $$u_i = (EP) f_i - h_i f_i^2 - D s_i ,$$

where, as in equations (5)-(9) :

u_i = partner i's expected utility,

EP = the expected total net income to the entire enterprise,

D = the fixed initial (investment) cost of the joint venture,

$s_i \equiv A_i/D$ = partner i's (fractional) share of the fixed cost of the joint venture,

f_i = partner i's (fractional) share of the total net income, P, and,

$h_i = a_i \text{ var } P$, where $a_i \geqslant 0$ is a parameter that measures partner i's aversion to risk.

In this appendix (as distinct from the model of Section V) we want to allow for the possibilities that : (1) the two partners may discount future cash flows at different rates, and (2) that they attach different subjective probabilities to alternative profit outcomes P. Hence we modify equation (A-1) to read :

(A-2) $$u_i = v_i f_i - h_i f_i^2 - D s_i .$$

Here v_i is the expected *discounted* total net income of the two partners, calculated with partner i's discount rate, and with his subjective probability distribution as to future profits of the enterprise. Also, h_i must also be correspondingly reinterpreted to reflect the variance of the discounted net income for partner i.

The parameters of the joint-venture agreement, f_1, f_2, s_1, and s_2, are constrained by :

(A-3) $$f_1 + f_2 = s_1 + s_2 = 1,$$

(A-4) $$f_i \geqslant 0, \quad i = 1, 2.$$

The data of the model are summarized in v_1, v_2, D, h_1, and h_2. We assume :

(A-5) $$v_1, v_2, D > 0,$$

(A-6) $$h_1, h_2 \geqslant 0.$$

It is also natural to assume that each partner views the *total* enterprise as profitable, in expected value, i.e.,

(A-7) $$v_1 > D, \quad v_2 > D.$$

(Of course, the realized profits might be negative.)

Let u_i^0 denote partner i's minimum acceptable level of expected utility, and let A denote the region of agreements acceptable to both partners. This region is bounded by the constraints (A-3) and (A-4) and by the two curves :

(A-8) $$s_i = \frac{v_i f_i - h_i f_i^2 - u_i^0}{D}, \quad i = 1, 2.$$

Without loss of generality, we can make the convention that :

(A-9) $$D = 1,$$

which is equivalent to choosing the units for the utility scales. With this convention, (A-8) becomes :

(A-10) $$s_i = s_i^0(f_i) \equiv v_i f_i - h_i f_i^2 - u_i^0, \quad i = 1, 2.$$

and (A-7) becomes :

(A-11) $$v_i > 1, \quad v_2 > 1.$$

Note that :

$$s_i^0(0) = -u_i^0,$$

$$s_i^0(1) \geqslant \text{ or } \leqslant 1 \text{ as } v_i - 1 \geqslant \text{ or } \leqslant h_i + u_i^0.$$

If $s_i^0(1) < 1$, then the venture is sufficiently risky so that partner i would not want to undertake the venture entirely alone, even though he might want a part of it.

As illustrated in Figures 2 and 4, the acceptable region A is not empty if and only if there is an f_2 between zero and one such that :

$$1 - s_1^0(1 - f_2) \leqslant s_2^0(f_2),$$

or alternatively, if there exist f_1 and f_2 satisfying (A-3) and (A-4) such that :

(A-12) $$s_1^0(f_1) + s_2^0(f_2) \geqslant 1.$$

We can also interpret (A-12) as follows. Given f_i, $s_i^0(f_i)$ is the maximum share of the fixed cost that partner i would be willing to pay. For an acceptable agreement, these two maximum shares must add up to at least unity.

We now consider two ways of accounting for risk in the joint venture. The first is described in the text, and is embodied in equation (A-2), with h_1 and h_2 strictly positive. This formulation, sometimes called the « mean-variance » model, might describe the behavior of the managers of the parent firms, or possibly the managers in the parent firms who are responsible for negotiating the joint venture. The mean-variance model is commonly used in the analysis of corporate finance and securities markets. It is well-known, however, that this model is not in general consistent with the von Neumann-Morgenstern expected-utility model usually used in economic theory outside the field of finance (see, for example, Borch, 1969, and Fishburn, 1985). The comparison of the mean-variance and expected-utility approaches in the context of our model is further complicated by two features : (1) the agents in our model are evaluating stochastic *sequences* of cash flows, rather than (one-dimensional) stochastic variables ; (2) the cash flows will not be directly « consumed » by the agents, but will be used in some way or other to evaluate the performance of the agents, or their companies. In the second circumstance, one says that the agent's preferences among stochastic cash flows are « induced » by their use in the evaluation of performance. It is known that such induced preferences need not satisfy the axioms of von Neumann-Morgenstern expected-utility theory (see Machina, 1984, and the references cited here).

In another approach, current theories of corporate finance (*) typically imply that, from the point of view of the stockholders of the parent firms, the correct way to take account of risk is through the cost of capital to the firm. That is to say, the rate of return that the capital market (and thus the shareholders) will require of the firm will depend on the risk attributes of the firm as a whole. Engaging in the joint venture will add a new risk to the « portfolio » of risks that the firm already is subject to. Adding this new risk may decrease or increase the cost of capital to the firm as a whole, depending on whether the addition of the new risk decreases or increases the degree of non-diversifiable risk of the firm as a whole. If the joint venture is « small » relative to the parent firm, then the risk attributes of the parent firm will remain approximately unchanged ; this would imply that h_i is approximately zero. On the other hand, if the size of the joint venture is significant compared to that of the parent firm, and if its risk attributes are significantly different from those of the parent firm, then h_i will be significantly different from zero.

In view of all of these considerations, we take the position that our particular use of the mean-variance approach represents a roughly plausible behavioral hypothesis, but we do not attempt to rationalize it fully from some complete model of rational choice under uncertainty.

In the following development, we consider two cases. In the first case, h_1 and h_2 are strictly positive. This corresponds to the behavior of risk-averse managers, and/or to the situation in which the addition of the joint venture *adds* to each parent firm's cost of capital, and the joint venture's size is significant. In the second case, h_1 and h_2 are both zero. This corresponds to the situation in which the managers are risk-neutral, and the joint venture has the same risk attributes as each parent firm and/or the size of the joint venture is relatively insignificant. In the first case, the optimal negotiation outcomes will typically be in the *interior* of the acceptable set, and will all have the same value of f_1 and f_2. In the second case, the optimal negotiation outcomes will lie on the *boundary* of the acceptable set. Since in practice the outcomes of negotiation are often *not* on the boundary of the acceptable set, this raises some question about the adequacy of the current theories of corporate finance to explain the way firms react to risk. (Another explanation is proposed at the end of the Appendix.)

Case I. *h_1 and $h_2 > 0$.*

We now characterize the set of optimal outcomes of negotiation. Recall that an acceptable outcome is optimal if there is no other outcome that makes one partner better off without making the other partner worse off. Equivalently, an acceptable outcome is optimal if, for some number u_1, it maximizes partner 2's expected utility among the set of all acceptable outcomes that give partner 1 an expected utility of at least u_1. We shall show that an outcome is optimal if and only if $f_1 = \hat{f}_1$ and $f_2 = \hat{f}_2$, where :

$$\text{(A-13)} \qquad \hat{f}_2 = \frac{h_1}{h_1 + h_2} + \frac{v_2 - v_1}{2(h_1 + h_2)}, \qquad \hat{f}_1 = 1 - \hat{f}_2,$$

provided $0 \leqslant \hat{f}_2 \leqslant 1$.

To prove (A-13), we first show that an outcome is optimal if and only if it maximizes $u_1 + u_2$. To see this, note that if the expected-utility pair (u_1, u_2) is feasible, then for any number v so is the pair $(u_1 + v, u_2 - v)$; just change s_1 to $s_1 - v$ and s_2 to $s_2 + v$. Hence, if (u_1, u_2) is feasible, so are all pairs (u_1', u_2') such that :

$$u_1' + u_2' = u_1 + u_2 .$$

If (u_1, u_2) and (u_1', u_2') are feasible, and :

$$u_1 + u_2 < u_1' + u_2',$$

then write :

$$u_1' + u_2' = u_1 + u_2 + v,$$

with v positive. Then $(u_1, u_2 + v)$ is feasible, and so (u_1, u_2) is not optimal. Hence the optimal outcomes are those that maximize $u_1 + u_2$.

Now note that :

$$\text{(A-14)} \qquad u_1 + u_2 = v_1 f_1 - h_1 f_1^2 + v_2 f_2 - h_2 f_2^2 - 1,$$

since $s_1 + s_2 = 1$ and $D = 1$. Thus the sum of the expected utilities does not depend on s_1 and s_2. Hence an outcome is optimal if and only if $f_1 = \hat{f}_1$ and $f_2 = \hat{f}_2$, where $\hat{f}_1$ and $\hat{f}_2$ maximize (A-14) subject to $f_1 + f_2 = 1$ (provided $(0 \leqslant \hat{f}_i \leqslant 1)$). The Lagrangean expression for this maximization problem is :

$$L = v_1 f_1 - h_1 f_1^2 + v_2 f_2 - h_2 f_2^2 - \lambda(f_1 + f_2 - 1),$$

and the first-order conditions for an interior maximum are :

$$\text{(A-15)} \qquad v_1 - 2h_1 f_1 = v_2 - 2h_2 f_2 = \lambda, \qquad f_1 + f_2 = 1.$$

Equations (A-13) and (A-14) have an interesting interpretation. (A-14) gives the size of the total « pie » that is available to be shared, and this pie can be shared in any way by suitably choosing s_1 and s_2. The *total size* of the pie is maximized by choosing f_1 and f_2, which effectively amounts to sharing the risk between the partners in an optimal way. The solution of these equations is (A-13). (In the special case in which $v_1 = v_2$, equation (A-13) becomes equation (17) of Section III.)

It is interesting to consider how the set of optimal outcomes may change if one imposes additional

(*) See, for example (Brealey and Myers, 1981), especially Chapter 9.

constraints on the acceptable set. For example, suppose that partner 1 has a limit, say $\bar{s}_1$, on the amount it can invest in the joint venture. This will impose the additional constraint :

$$s_1 \leqslant \bar{s}_1 ,$$

or equivalently,

(A-16) $$s_2 \geqslant 1 - \bar{s}_1 ,$$

on the acceptable set. Figures 6 and A-1 illustrate what happens to O, the optimal set, when the line segment determined by (A-13) (the old optimal set) does not lie entirely within the new acceptable set. In each case, the new acceptable set, A, is the part of the lens-shaped area that lies above the line, $s_2 = 1 - \bar{s}_1$. In Figure 5, part of the line segment determined by (A-13) lies in A, and the new optimal set O is made up of that part of the line segment together with a piece of the boundary of A that lies on the line $s_2 = 1 - \bar{s}_1$. In Figure A-1, none of the

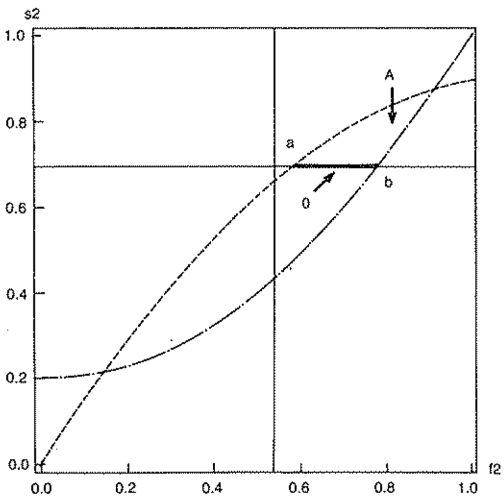

FIG. A-1. — Acceptable and optimal outcomes, with constraint on firm 1's optimal investment, case 2. $D = 10$, $EP = 16$, $h_1 = 8$, $h_2 = 7$.
—·— $u_1 = 0$, ---- $u_2 = 0$.

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old optimal set is acceptable, and the new optimal set is entirely on the boundary of A that lies on $s_2 = 1 - \bar{s}_1$. In each figure, as one moves along O from point a to point b one increases partner 2's expected utility and decreases partner 1's expected utility.

Case II. $h_1 = h_2 = 0$.

In this case, partner i's expected utility ($i = 1, 2$) is :

(A-17) $$u_i = v_i f_i - s_i ,$$

(we continue the convention that $D = 1$). The acceptable set A is bounded by the constraints (A-3) and (A-4), and by the lines :

(A-18) $$s_i = s_i^0(f_i) \equiv v_i f_i - u_i^0, \quad i = 1, 2.$$

(This is illustrated in Figure 8, with $v_2 > v_1$ and $u_1^0 = u_2^0 = 0$.)

One can show that, if $v_j > v_i$, then the optimal set, O, is the set of all acceptable outcomes for which $f_j = 1$. (Again, see Figure A-2.) To see this, suppose that $v_2 > v_1$, and maximize partner 2's expected utility in the acceptable set given that partner 1's expected utility is fixed at some number u_1. By (A-17) :

$$s_1 = v_1 f_1 - u_1 .$$

Hence :

(A-19) $$\begin{aligned} s_2 &= 1 - s_1 , \\ &= 1 - v_1 f_1 + u_1 , \\ &= 1 - v_1(1 - f_2) + u_1 , \\ &= v_1 f_2 + (1 - v_1 + u_1). \end{aligned}$$

(A-20) $$\begin{aligned} u_2 &= v_2 f_2 - s_2 , \\ &= (v_2 - v_1) f_2 - (1 - v_1 + u_1). \end{aligned}$$

Since $v_2 > v_1$, (A-20) is maximized by taking :

(A-21) $$f_2 = 1.$$

It follows from (A-19) that, for $f_2 = 1$:

(A-22) $$s_2 = 1 + u_1 ,$$

and from (A-17) that :

(A-23) $$u_2 = v_1 - (1 + u_1), \quad \text{or}$$
$$u_1 + u_2 = v_1 - 1.$$

Equations (A-21)-(A-23) have an interesting interpretation. Since partner 2 places a higher value on the uncertain (discounted) net income than partner 1 does ($v_2 > v_1$), it is optimal for partner 2 to receive

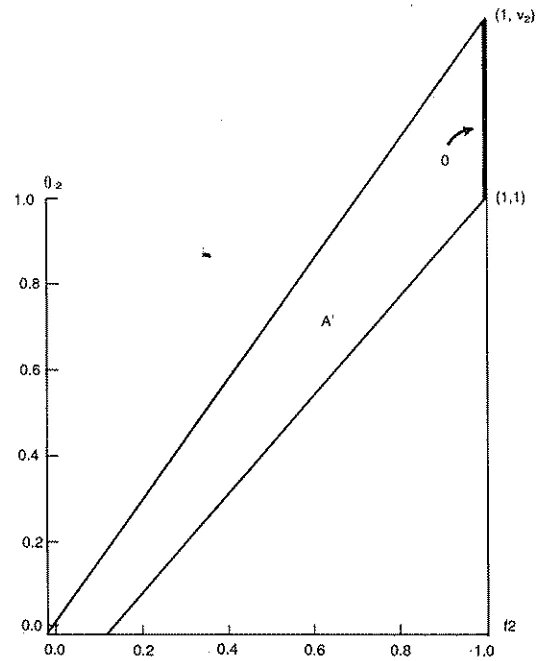

FIG. A-2. — Acceptable and optimal outcomes. $h_1 = h_2 = 0$, $v_2 > v_1$.

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all of the net income ($f_2 = 1$), and compensate partner 2 with some fixed payment. The total fixed cost of the joint venture is 1 (recall the convention that $D = 1$). Hence (A-22) has the interpretation that partner 2 pays partner 1 an « up-front » fee of u_1, in addition to paying the entire fixed cost. This is equivalent to partner 2 acquiring the joint venture totally, and compensating partner 1 by a fixed amount u_1 for partner 1's contribution. The amount of this compensation will be constrained by (A-23) and the constraints :

(A-24) $$u_1 \geqslant u_1^0, \quad u_2 \geqslant u_2^0 .$$

Thus, according to (A-21)-(A-24), partner 1 acquires the joint, venture but the two partners divide the total net profit of $v_1 - 1$ (as valued by partner 1) in some arbitrary proportions within the acceptable range.

A difficulty with this solution arises if the success of the joint venture requires a *continuing* contribution by partner 1 of some resources, skills, or management. In this case, partner 1 might not have the *incentive* to make such a continuing contribution if it received a *fixed* compensation, i.e., a compensation independent of the realized net operating revenues. Such a consideration might lead partner 2 to prefer an outcome in which f_1 is strictly positive, and s_2 is accordingly reduced. In these circumstances, the analysis of optimal negotiating outcomes is beyond the scope of the present model, but is possible in a more comprehensive model (*).

Finally, we conclude by remarking that, in Case II, if $v_1 = v_2$ then *all* acceptable outcomes are optimal.

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(*) This is the so-called *principal-agent* problem ; see, e.g. (Radner, 1987).

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