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# TECHNOLOGY TRANSFER: PARTNER SELECTION AND CONTRACT DESIGN WITH FOREIGN FIRMS IN THE INDIAN BIOTECHNOLOGY SECTORS

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## I. INTRODUCTION

TECHNOLOGICAL knowledge can be transferred from one firm to another through technology purchases, technology collaboration, or spillovers. The focus of this paper is on voluntary transfers of technological knowledge between firms of different nationalities and hence excludes spillovers, which are an involuntary leakage of knowledge from one firm to another in the form of externalities. Technology purchase refers to market purchase of machines, patents, licenses, or even firms. Technology collaboration is defined as technology transfer in which a foreign firm has a positive equity stake. Technology collaboration may or may not take the legal form of a joint venture. Technology collaboration is distinct from technology purchase in that it involves joint control of resources for an agreed period of time, and the maintenance of networks between the different agents concerned through formal or informal contractual commitments.

The nature of commodity transactions involved in a technology transfer is thus different in technology purchase and technology collaboration. In the former, a "knowledge artifact" such as a license is exchanged for money and the "buying firm" bears all the risks of "redesign" or adaptation of the product to the conditions of the market. In the latter, the "knowledge base" of a firm is shared and invested with another firm, to create a product or process of enhanced economic value. Here the risk of adaptation of the innovation is shared by both firms. In the past, most of the developing countries promoted technology transfer in the form of purchases rather than collaboration, as it was felt that they offered a better opportunity to have

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access to state-of-the-art technology. It seemed unlikely that in collaboration, a developed country firm would transfer state-of-the-art technology to a developing country firm. However, the rise of East Asian countries such as Taiwan and the Republic of Korea that have exploited foreign technology collaboration to integrate new knowledge, is leading governments to reflect over the earlier ranking of these two types of technology transfer.

Most of the existing studies on North-South technology transfer however do not distinguish between the different forms of technology transfer, or explain the "partner selection criteria" and "contract design" that sustain such international cooperation. This could be due to the fact that until recently, in most of the developing countries, local firms could not freely initiate strategic alliances with foreign firms for technology transfer. Information on foreign firms was not easily accessible and contractual commitments were often subject to constraining government regulations. However this situation has changed significantly in the 1990s in many of the developing countries, and new technology incorporation through international alliances has become a viable option for developing country firms. In this connection, this paper attempts to contribute to the study of technology transfer to developing country firms through a case study of India, with the biotechnology sectors as the knowledge-based industry of reference. It tries to answer the following questions: What are the criteria for the choice of a type of transfer initiated, i.e., technology purchase or technology collaboration? What are the criteria for "partner selection" in any type of cooperation from the point of view of the Indian firm and from the point of view of the foreign firm? In technology collaboration, what are the determinants of the "contract design" or equity participation of the alliance partners? What are the distinguishing features of technology cooperation of firms that are already active in the biotechnology sectors?

The article first develops a game theoretical model to explain the strategic foundations of technology transfer between developed and developing country firms. It presents three propositions to explain the choice of the mode of technology transfer, partner selection criteria, and degree of foreign equity participation, given asymmetric technological competence between developed and developing country firms. Then it tests the propositions of the game theoretical model using real data on technology transfer to Indian firms in the biotechnology sectors. The empirical investigation partly confirms the theoretical proposition according to which competent local firms prefer to buy technology rather than acquire it through collaboration, while competent foreign firms prefer to transfer technology through collaboration rather than sell it to a local firm. The study also indicates that problems of imperfect circulation of information may be the cause of the lack of sufficient collaboration with European firms.

Modern biotechnology refers to a set of techniques such as genetic engineering, cell and tissue culture, protein synthesis, and enzymology that involve manipulation of the genetic patrimony of an organism. They have emerged from recent developments (since 1975) in the biological sciences such as biochemistry, biophysics, molecular biology, microbiology, cellular biology and genetics. Integration of biotechnology has given rise to new products and new production processes in industries such as pharmaceuticals, chemicals, agriculture, food, agribusiness, environmental control, etc. and new search methods for chemical and biological entities (OTA 1991). The biotechnology sectors have been chosen for two reasons. Firstly, biotechnology is one of the new knowledge-based industries, the others being microelectronics, telecommunications and new materials, in which asymmetry between developed and developing countries is very large. The asymmetry lies not only in the endowment of technological knowledge in firms, but also in the scientific knowledge of the public laboratories, weaker links between public laboratories and private firms, less developed capital markets, and of course, much lower investment of resources by the government and firms in knowledge creation. Secondly, among the new science-based technologies, biotechnology is perceived to be most important for the resolution of certain essential problems faced by the less affluent masses such as access to food, health care products, and clean environment. India presents an interesting case study because it is one of the countries of the developing world that had declared investment in biotechnology to be strategic to its national program of development very early in the beginning of the 1980s, soon after the impact of biotechnology became obvious in the United States. This period of growing awareness of the importance of biotechnology coincided with the initiation of economic liberalization, making foreign collaboration yet another option for the integration of biotechnology (Ramani and Visalakshi, forthcoming).

The paper is organized in five sections. Section II presents a brief outline of the literature on technology transfer to Indian firms and procedures for the initiation of foreign technology agreements. Section III introduces the game theoretical model that examines the strategic foundations of technology transfer. Section IV presents the data and the methodology used for the empirical verification of the theoretical model. Finally Section V contains our reflections on possible policy recommendations.

## II. TECHNOLOGY TRANSFER: THEORY AND REALITY

### A. *The Debate on Technology Transfer to Indian Firms*

The literature on the R&D activities of Indian firms does not distinguish between technology purchase and technology collaboration, clumping them both together as technology transfer or technology imports. One of the central debates related to technology transfer is its impact on the creation of indigenous competence. There are three different types of conclusions corresponding to three different concepts on the relationship between knowledge obtained from abroad and knowledge generated or existing within Indian firms.

Some economists assert that internal R&D is a substitute for import of technology. Desai (1980, 1988) argues that Indian R&D, given its limited sources, can only focus on short-term projects and therefore it is more economical to buy rather than develop technology that requires medium- to long-term investment in knowledge generation. Basant and Fikkert (1996) find that the stock of technology imports is always significantly and negatively related to in-house R&D. They argue that since returns to technology imports are greater than to internal R&D and since both are substitutes in knowledge production, firms buy from abroad when they can. Spillovers from abroad, on the other hand, are significantly and positively related to in-house R&D indicating that such spillovers are complements to in-house R&D.

Others, however, assert that technology imports are a complement to internal R&D (Katrak 1985, 1989, 1994; Deolalikar and Evenson 1989; Siddharthan 1998; Siddharthan and Agarwal 1992). Here the basic assumption fuelling the analysis is that Indian R&D is mainly adaptive rather than innovative. Therefore in order to be efficient in identifying and adapting useful information, processes, or products obtained from Western firms, it is necessary to maintain a sufficient level of knowledge through engaging in internal R&D. Siddharthan (1988) further notes that this complementarity is a decreasing function of the technological sophistication of the sector concerned. However Siddharthan and Agarwal (1992) find that when other firm characteristics, like past successes or expenditure on skilled personnel are taken into account, R&D intensity ceases to have any relationship with technology imports. Kumar and Saqib (1996) call for a fresh look into this debate, as they find no significant relation between technology imports and R&D intensities.

Such diverse results on the impact of technological imports could stem from the fact that the conclusions are based on different databases and also because the impact of knowledge creation (internal R&D) or technology transfer is measured in a variety of ways, centered around indicators of efficiency such as the impact on output, sales, or factor productivity.

### B. *Regulation of Technology Transfer through Foreign Technology Agreements*

Technology agreements refer to the spatial diffusion of technology through sale of equipment, patents, licenses, know-how, design, trademarks, models; provision of technical services for the construction of plants or production systems; or training of personnel. Technology agreements involve payments in the form of lump sum fees or royalties. They may or may not be associated with foreign direct investment in the form of equity participation. They are distinct from portfolio investment in financial markets. Thus technology agreements include both forms of technology transfer: technology purchase (with zero equity participation) and technology collaboration (with positive equity participation).

Prior to the initiation of the economic reform measures in 1991, technology agreements had to be a necessary component of any foreign direct investment because the government considered that foreign investment should be a vehicle for technology transfer. At the same time, since self-sufficiency and import-substitution were the cornerstones of industrial policy, all the technology agreements had to be carefully scrutinized to ensure that they represented a transfer of modern technology that was necessary to the economy and unavailable locally (Stoever 1989). The equity structure accompanying a collaboration limited the participation of the foreign partner to 40 per cent unless the product was entirely exported or considered otherwise essential. The licensing procedure for foreign collaboration was lengthy, complicated and cumbersome. Payments in the form of lump sum fees were preferred to royalties for technology agreements in order to minimize the uncertainty and augment the control over foreign exchange holdings. According to Stoever, such a cautious approach succeeded in conserving foreign exchange but at the same time, it remained to be determined whether such a policy was optimal in terms of maximizing knowledge transfer or foreign exchange earnings from the rest of the world. Jagdish Bhagwati also points out that the "restrictions on incoming direct foreign investment have also reduced the absorption of new technology from this source. While the Korean and the Japanese growth of domestic technological capabilities was not based on direct foreign investment, these nations did not have the baggage of India's regime of 'don'ts' that also reduced other forms of technical absorption and innovation" (Bhagwati 1994, p. 62).

The market for knowledge changed significantly in India with the initiation of the "New Industrial Policy" in 1991, whose target was to boost industrial growth through a more efficient allocation of resources, deregulation and global integration. It also included a dramatic change in foreign investment policy. The Government of India simplified the procedure for the entry of foreign capital by permitting an "automatic route" of approval for a large set of industries listed in a document known as "Annexe III" issued by the Ministry of Industry. This list has expanded over the years and indicates the sectors and items that do not need to be screened by the government and that are eligible for automatic approval by the Reserve Bank of India for foreign equity participation of up to 50 per cent, 51 per cent, or 74 per cent depending on the sector concerned. Only "high-priority sectors" serving national interests, sectors reserved for the small-scale industries, certain financial services (like banking) and large real estate investments need government approval now.

Most of the biotechnology-related sectors belong to "Annexe III" with automatic approval for equity participation by foreign firms up to 51 per cent. Foreign direct investment does not require any form of technology agreement with an Indian partner. The latter is also channeled either through an "automatic approval" or a "government approval" route by the Ministry of Industry. Here the type of approval does not depend on the industrial sector or item concerned, but the magnitude of the monetary payment involved. Automatic approval is granted to foreign agreements whose lump sum and royalty payments fall within certain limits fixed by the Indian government.[1] Collaboration may or may not be accompanied by foreign equity participation. An indicator of the impact of the liberalization policy is that while the average number of foreign technology agreements per year between 1987 and 1990 was 762, it rose to 2,096 between 1992 and 1995.[2]

## III. A GAME THEORETICAL MODEL OF TECHNOLOGY TRANSFER[3]

Let us consider a game with two players: a firm from a less developed country or a "ldc" firm and a foreign firm "f." In what follows we represent technology transfers as possible strategies in a sequential game where the ldc firm first chooses whether or not to solicit the foreign firm, and the foreign firm either chooses to agree (i.e., say "yes") or refuse (i.e., say "no") when solicited. If the foreign firm agrees then the two firms negotiate certain variables that determine the division of expected profit. Then the game ends.

The ldc firm is assumed to play first to reflect the reality of international technology transfer, where the uncertainty is related to the market rather than to the technology. In other words, the internal developing country market is better known to the local partner or ldc firm, which then explores the possibility of technology transfer with the foreign firm. This means that the game considered is a "Stackleberg" game, where the first player enjoys first mover advantages. This also corresponds closely to the reality of many international alliances.

As the first player, the ldc firm has two strategic options by which to commercialize an innovation that has already been developed by the foreign firm: own R&D, or technology transfer from the foreign firm. Let $p_{ldc1}$ represent the technological competence of the ldc firm as a result of its own R&D efforts. It is the probability that the ldc firm independently develops the innovation through its own R&D. In any form of technology transfer, the information obtained changes the technological competence of the ldc firm, and its probability of success increases from $p_{ldc1}$ to $p_{ldc2}$. Thus $p_{ldc2} \geq p_{ldc1}$ can be considered as the learning capacity of the ldc firm.

Let the profit associated with the successful commercialization of the innovation

[1] Automatic approval is granted within fifteen days for foreign technology agreements involving a lump sum payment of up to U.S.$2 million (net of taxes), royalty up to 5 per cent (net of taxes) on domestic sales and 8 per cent (net of taxes) on exports subject to a total payment of 8 per cent on sales over a ten-year period from the date of agreement or seven-year period from the onset of production.

[2] The figures for the total number of cases of foreign collaboration between 1986 and 1996 were obtained from various homepages of the departments of the government of India available on the internet.

[3] This section is largely based on an earlier version of this model which was described in S. V. Ramani (2000).

in the ldc market be $\Pi$. Suppose that the ldc firm decides to create the innovation through its own R&D efforts. Then the expected payoff to the ldc firm from own R&D is $\Pi \cdot p_{ldc1}$ and the payoff to the foreign firm is zero.

Now two kinds of technology transfer can be envisaged, involving one of two different commodities: either a "knowledge artifact" such as a license or the "knowledge base" of the foreign firm. These are two distinct and different commodities and their magnitudes are not additive (e.g., one cannot add pears and apples). The former is referred to as technology purchase and the latter as technology collaboration.

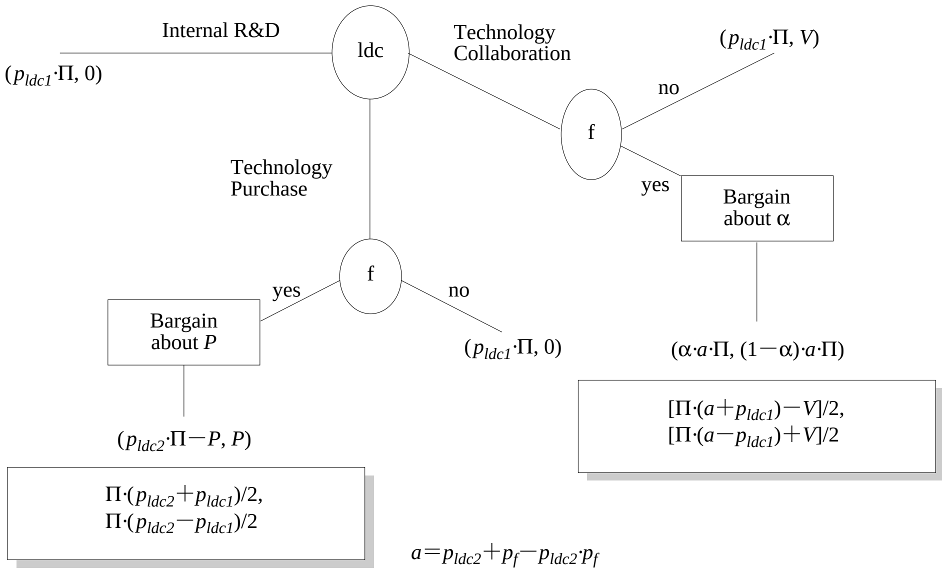
*Technology purchase:* This refers to the sale of a knowledge artifact in the form of an "exclusive license" by the foreign firm to the ldc firm. In other words, either the foreign firm sells a license exclusively to the ldc firm or it does not sell a license. When the foreign firm sells the license, it earns a revenue equivalent to the price of the license negotiated $P$. The present cost of production of the license for the foreign firm is assumed to be zero, as it represents the sunk costs of the past. Thus, when the foreign firm does not sell the license, it earns zero revenue. From the point of the view of the ldc firm, if it obtains information through a technology purchase, its payoff is $\Pi \cdot p_{ldc2}$, otherwise it is $\Pi \cdot p_{ldc1}$. The variable negotiated between the two firms in this transfer is the price of the license $P$. Finally, in a technology purchase, the ldc firm bears all the risk of "redesign" or adaptation of the product to the conditions of the ldc market.

*Technology collaboration:* This refers to the sale of the knowledge base of the foreign firm with an economic value $V$, to be transformed, with the collaboration of the ldc firm, into an artifact or a new commodity with an economic value of $\Pi$. Now knowledge is a non-rival good, i.e., even when a firm sells its knowledge, it still retains its knowledge base. Thus $\Pi \geq V$. When the foreign firm sells its knowledge in a collaboration, it gains a share $(1 - \alpha)$ of $\Pi$ where the share $\alpha \in (0, 1)$ is the variable of negotiation between the two firms. When the foreign firm does not sell its knowledge base to the ldc firm, it is left with $V$. The payoff for the ldc firm from entering into a technology collaboration is $\alpha \cdot \Pi$, and the payoff to the ldc firm from not entering into a technology collaboration is $\Pi \cdot p_{ldc1}$. In the case of technology collaboration, both firms jointly bear the risk of adapting the technology developed by the foreign firm to the conditions of the ldc market.

Since the knowledge artifact in the form of a license with a value $P$ is a different commodity from the knowledge base of the foreign firm with a value $V$, the payoffs associated with the transaction of the "knowledge artifact" and the "knowledge base" are independent of $V$ and $P$, respectively.

Let $p_f$ be the probability of the foreign firm of successfully "redesigning" the innovation to the conditions of the ldc market alone. Assuming that $p_{ldc2}$ and $p_f$ are independent and there is no problem of moral hazard, the probability of success of the joint venture is $[1 - (1 - p_{ldc2}) \cdot (1 - p_f)]$ or $(p_{ldc2} + p_f - p_{ldc2} \cdot p_f)$.

Fig. 1. Game of Technology Transfer




Note: The vectors in the boxes represent payoffs after negotiation.

Thus the technological competence of the alliance is higher than the probability of success of both the ldc firm after purchase of information $p_{ldc2}$ and the foreign firm $p_f$. However collaboration is a double-edged sword for both firms, because while it increases the probability of success, at the same time, it also entails sharing of profit. The payoffs to the ldc firm and the foreign firm from the collaboration are $[\alpha \cdot (p_{ldc2} + p_f - p_f \cdot p_{ldc2}) \cdot \Pi]$ and $[(1 - \alpha) \cdot (p_{ldc2} + p_f - p_f \cdot p_{ldc2}) \cdot \Pi]$, respectively. The game is given in Figure 1.

Two important assumptions are made for simplification of the game in order to focus on the partner selection problem and incentives for cooperation. They can be removed in further extensions and such removal is likely to change the results.

A1: All the parameters constituting the game are common knowledge to both firms.

A2: There is no moral hazard from either the foreign or ldc firm. The foreign firm has no incentive to commercialize the innovation alone in the ldc market, i.e., $p_f \cdot \pi < V$ and the ldc firm cannot resell the technology to any other firm or sell the product outside of the ldc market.

In order to resolve the negotiation problem with respect to $P$ and $\alpha$, we consider the simplest game theoretical solution namely the Nash bargaining solution. This means that for the two firms we first consider the difference between what they would obtain if they entered into a transaction, and what they would obtain if they disagreed, and could not enter into the transaction. Then the equilibrium value of the negotiated variable is found by maximizing the product of the difference of the two payoffs with respect to the variable being negotiated.

In the present game, the disagreement points are assumed to be the payoffs associated with the players when the foreign firm says "no" on being solicited by the ldc firm. It may be noted that they are different under the two forms of technology transfer for the foreign firm, as explained above.

Thus in the Nash equilibrium, the negotiated price $P^*$ is the solution to equation (1) and the negotiated share of the ldc firm $\alpha^*$ is the solution to equation (2):

$$\underset{\{P\}}{\text{Max}}(p_{ldc2} \cdot \Pi - P - p_{ldc1} \cdot \Pi) \cdot P, \tag{1}$$

$$\underset{\{\alpha\}}{\text{Max}}[\alpha \cdot (p_{ldc2} + p_f - p_f \cdot p_{ldc2}) \cdot \Pi - p_{ldc1} \cdot \Pi)] \times [(1-\alpha) \cdot (p_{ldc2} + p_f - p_f \cdot p_{ldc2}) \cdot \Pi - V]. \tag{2}$$

This gives us:

$$P^* = \frac{\Pi(p_{ldc2} - p_{ldc1})}{2}, \tag{3}$$

$$\alpha^* = \frac{\Pi(p_{ldc2} + p_f - p_{ldc2} \cdot p_f + p_{ldc1}) - V}{2 \cdot \Pi \cdot (p_{ldc2} + p_f - p_{ldc2} \cdot p_f)} . \tag{4}$$

Let $\pi_{ldc}$ and $\pi_f$ be the payoffs to the ldc and foreign firm, respectively. Then substituting for the values of $P^*$ and $\alpha^*$ from equations (3) and (4) we obtain the following payoff structure after negotiation (see Figure 1).
When the ldc "commercializes alone":

$$\{\pi_{ldc} = p_{ldc1} \cdot \Pi; \;\; \pi_f = 0\}.$$

When the ldc and foreign firm cooperate through a "technology purchase":

$$\{\pi_{ldc} = (p_{ldc2} + p_{ldc1}) \cdot \Pi / 2; \;\; \pi_f = (p_{ldc2} - p_{ldc1}) \cdot \Pi / 2\}.$$

When the ldc and foreign firm cooperate through a "collaboration":

$$\{\pi_{ldc} = [(a + p_{ldc1}) \cdot \Pi - \text{V}] / 2; \;\; \pi_f = [(a - p_{ldc1}) \cdot \Pi + V] / 2\}.$$

where $a = p_{ldc2} + p_f - p_{ldc2} \cdot p_f$.

The Nash equilibrium[4] for this game is found by backward induction and the following results can be derived subsequently.

[4] Nash equilibrium refers to a strategy profile from which no player has any incentive to deviate, i.e., a strategy for each player such that neither player has any incentive to deviate from her or his Nashstrategy when the other player is also playing her or his Nash strategy. The Nash equilibrium

Comment:

(i) For a foreign firm, if a ldc firm offers to buy technology, it earns more by selling the technology than by refusing.

(ii) For a foreign firm, the payoff under technology collaboration is always higher than under technology purchase.

(iii) For an ldc firm technology purchase is preferred to in-house development only when $p_{ldc2} > p_{ldc1}$.

All the three points of the comment are derived from simple manipulation of the payoff structure of the game given in Figure 1.

Proposition 1 on transfer type:

1.1. The choice of the "transfer type" is a function of the technological competence of the foreign firm $p_f$, the learning capacity of the ldc firm $p_{ldc2}$ and the sector in which the cooperation is embedded $(V, \Pi)$. Let $C^{buy}$ represent the set of $(p_{ldc2}, p_f)$ under which the ldc firm prefers to initiate a technology purchase rather than a collaboration and the foreign firm sells the technology. Let $C^{collab}$ represent the set of $(p_{ldc2}, p_f)$ under which the ldc firm prefers to initiate a technology collaboration and the foreign firm agrees. Then

$$C^{buy} = \{(p_{ldc2}, p_f) \mid p_f \cdot (1 - p_{ldc2}) < \frac{V}{\Pi}\}, \tag{5}$$

$$C^{collab} = \{(p_{ldc2}, p_f) \mid p_f \cdot (1 - p_{ldc2}) > \frac{V}{\Pi}\}. \tag{6}$$

1.2. The higher the technological competence of the foreign firm $p_f$, the higher the probability of technology collaboration;

1.3. The higher the learning capacity of the ldc firm $p_{ldc2}$, the higher the probability of technology purchase;

1.4. The higher the ratio of the knowledge content $V$ involved in a sector to its market size $\Pi$, the higher the probability of a technology purchase.

Proof:

It can be noted that if the foreign firm is likely to say "no" to a collaboration, the ldc firm will never solicit it (for then it is better for the ldc firm to buy technology). Thus, an ldc firm will prefer to initiate a technology purchase rather than a technology collaboration if one of the following two conditions is satisfied:

(a) the foreign firm refuses to collaborate because its payoff is higher when it says "no" to a collaboration rather than when it says "yes"; i.e.,

strategy profile is considered to correspond to the prediction of the most likely outcome of a strategic situation.

$$[(a - p_{ldc1}) \cdot \Pi + V] / 2 < V,$$
$$\Leftrightarrow a - \frac{V}{\Pi} < p_{ldc1},$$
$$\Leftrightarrow a - \frac{V}{\Pi} < p_{ldc2},$$
$$p_f \cdot (1 - p_{ldc2}) < \frac{V}{\Pi}.$$

(b) or even if the foreign firm agrees to collaborate, the ldc firm earns a higher payoff from initiating a technology purchase rather than a collaboration; i.e.,

$$p_f \cdot (1 - p_{ldc2}) < \frac{V}{\Pi}.$$

The above two conditions give us the proposition. From equation (6) we can also deduce that $C^{collab}$ is non-empty if and only if $V < \Pi$.

The proofs of (1.2)–(1.4) follow directly from the definitions of $C^{collab}$ and $C^{buy}$.

Corollary: There is no technology transfer between the two firms when

$$(p_{ldc2}, p_f) \notin C^{collab} \text{ and } p_{ldc2} = p_{ldc1}.$$

Proof: When $(p_{ldc2}, p_f) \notin C^{collab}$, technology collaboration is not possible. However when $p_{ldc2} = p_{ldc1}$, the value of information from the technology purchase is zero. In this case, technology purchase also is of no worth to the ldc firm.

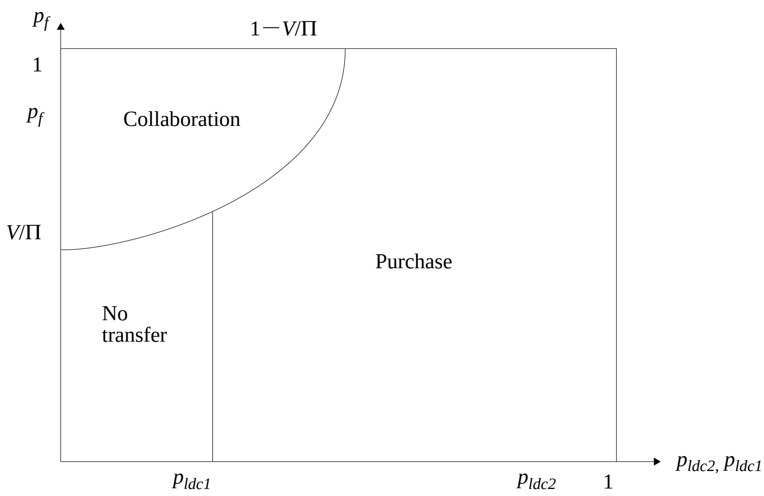
This then leads us to the following partition of the $(p_{ldc2}, p_f)$ space as shown in Figure 2. Three regions can be distinguished. When $(p_{ldc2}, p_f) \notin C^{collab}$ and $p_{ldc2} > p_{ldc1}$, there is a technology purchase. When $(p_{ldc2}, p_f) \in C^{collab}$, there is collaboration. Otherwise, there is no technology transfer.

The proposition indicates that if it is not profitable for a foreign firm to penetrate into an ldc market alone, it will have sufficient incentives to transfer technology relating to even non-obsolete or state-of-the-art technology, if it can earn rent in the ldc market through cooperation. For the foreign firm, if the probability of successfully redesigning the product to the ldc market alone is high, i.e., $p_f$ is high, it will never sell to a ldc firm, preferring to seek a ldc partner to collaborate with in the ldc market because the rents earned thus will be higher. By a similar argument, since a ldc firm bears all the risks and enjoys exclusive industrial rights over the innovation in a technology purchase, but has to share both in a collaboration, it will prefer to buy the information rather than enter into a collaboration, if it can learn sufficiently from the acquisition of information, i.e., if $p_{ldc2}$ is sufficiently high.

Proposition 2 on partner selection in a technology transfer:

In any technology transfer, the foreign firm prefers to cooperate with the ldc firm that has the highest learning capacity (i.e., ldc firm with highest $p_{ldc2}$). In technology

Fig. 2. Domain of Technology Transfer




collaboration, the ldc firm prefers to cooperate with the most competent foreign firm (i.e., foreign firm with highest $p_f$).

Proof:

Under both technology purchase and a collaboration, the payoff of the foreign firm increases with a higher learning capacity of the ldc firm $p_{ldc2}$. Therefore the foreign firm prefers to become a partner with the ldc firm that exhibits the highest $p_{ldc2}$. Similarly, in a collaboration, the payoff of the ldc firm increases with the redesign competence of the foreign firm $p_f$ and therefore it prefers to cooperate with the most competent foreign firm (i.e., with highest $p_f$). The appropriate derivatives of the payoffs after substituting for the Nash bargaining solution of $P$ and $\alpha$ are given below and it can be seen that the proposition follows directly from them.

$$\text{In a technology purchase: } \frac{d\pi_f}{dp_{ldc1}} < 0,\ \frac{d\pi_f}{dp_{ldc2}} > 0,\ \frac{d\pi_{ldc}}{dp_f} = 0, \tag{7}$$

$$\text{In a collaboration: } \frac{d\pi_f}{dp_{ldc1}} < 0,\ \frac{d\pi_f}{dp_{ldc2}} > 0,\ \frac{d\pi_{ldc}}{dp_f} > 0. \tag{8}$$

Proposition 3 on equity participation in a technology collaboration:

The foreign equity participation $(1 - \alpha)$ will be higher for:

3.1. Higher learning capacity of the ldc firm $p_{ldc2}$;
3.2. Higher competence of the foreign firm $p_f$;
3.3. Higher value of knowledge $V$; and
3.4. Lower expected profit $\Pi$.

Proof:

Taking the derivatives of $\alpha$* obtained in equation (4) shown below we get proposition 3:

$$\frac{d\alpha}{dp_{ldc1}} > 0,\ \frac{d\alpha}{dp_{ldc2}} < 0,\ \frac{d\alpha}{dp_f} < 0,\ \frac{d\alpha}{dV} < 0, \text{ and } \frac{d\alpha}{d\Pi} > 0. \tag{9}$$

## IV. EMPIRICAL INVESTIGATION: DATA, METHODOLOGY AND RESULTS

The objective of the empirical investigation was to examine if a database could be constructed on foreign collaboration in the Indian biotechnology sectors and whether by exploiting the database so constructed we could estimate empirical models of "transfer type," "contract design," and "partner selection criteria" to verify the three propositions presented in the previous section.

### A. *Data*

Recently, the Department of Scientific and Industrial Research, that functions under the Ministry of Science and Technology of the Government of India, has released information on the technology agreements with foreign firms in the Indian manufacturing sectors (India, DSIR 1994, 1995, 1996). The data are extremely aggregated. For each case of collaboration, the database identifies the name of the Indian and foreign partner, the region of the foreign partner, the sector to which the collaboration pertains and the degree of foreign equity participation. There is no information on the number of approvals that are actually granted. From this data set we derived a sample that contained collaboration in floriculture, aquaculture, chemicals, pharmaceuticals, agrochemicals, food additives, processed food, environment, energy, and biotechnology equipment, i.e., the principal sectors where modern biotechnology is integrated.

We then tried to obtain indicators of the knowledge base of the different partners. We were able to construct two types of indicators for the Indian firms but none for the foreign firms.[5] Firstly a firm was considered to have a strong knowledge base if its R&D laboratory was listed in the directory of the Department of Scientific and Industrial Research (India, DSIR 1996).[6] Secondly, since biotechnology is knowledge-intensive, a firm was also considered to have a strong knowledge base if it had already integrated or intended to integrate biotechnology in either its research, production or marketing activities. We could identify which of the firms in the sample

[5] We consulted standard biotechnology data bases like the Derwent Biotechnology abstracts but a majority of the small- and medium-sized foreign firms were not listed in the data base.

[6] This directory lists the firms undertaking R&D investment of U.S.$83,000 or more annually (Rs 2.5 million converted into dollars at the rate of Rs 30 = U.S.$1).

TABLE I

THEORETICAL AND EMPIRICAL VARIABLES

| Parameters of Game | Empirical Variables | Different Conditions of the Empirical Variables in the Data |
|---|---|---|
| $p_{ldc2}$ | *V1biotech* | Indian partner is involved in biotech; *V1biotech* = {Yes, No} |
| $p_{ldc2}$ | *V2R&D* | Indian partner has a recognized R&D laboratory; *V2R&D* = {Yes, No} |
| $p_f$ | *V3region* | Foreign partner's region profile; *V3region* = {NAFTA, EU, Asian countries, Other countries} |
| $V, \Pi$ | *V4sector* | Sector of collaboration; *V4sector* = {Pharmaceuticals, Chemicals, Agribusiness, Floriculture, Equipment} |
| Transfer type | *V5type* | Transfer type; *V5type* = {Technology purchase, Technology collaboration} |
| Contract design $\alpha$ | *V6* | Equity participation of Indian firm; $\alpha \in (0, 100)$ |
| $p_{ldc1}$, $P$ | | No data available. |

set were already active in biotechnology by checking the directory of biotechnology companies published by the Department of Biotechnology of the Government of India (Biotech Consortium India 1995). In some instances, when information on the nature of the collaboration clearly indicated that the associated Indian firm had integrated biotechnology in its activities, it was considered to be active in the biotechnology sectors, even if not listed in the Government directory.

Thus six empirical variables were constructed and related to the theoretical variables as shown in Table I. The following assumptions were also made on the empirical indicators:

(A3) The learning capacity, i.e., $p_{ldc2}$ of Indian firms with an R&D base is higher than that of Indian firms without an R&D base.

(A4) The learning capacity, i.e., $p_{ldc2}$ of Indian firms that are active in biotech is higher than that of Indian firms that are not active.

(A5) The technological competence for redesigning the product, i.e., $p_f$ of American and European firms is greater than that of Asian and other foreign firms.

## B. *Methodology*

We started with descriptive statistics in order to analyze the nature of each of the variables, their weight in the data set and their relationships to one another. Then models were constructed to test the predictions of the theoretical model developed in Section III.

Firstly, the absolute and relative frequency of each of the variables was computed. Since all the variables except *V6* were qualitative variables, Chi-square statistical tests were conducted to measure the correlation between pairs of variables. When Chi-square tests are used to evaluate the global relationships between pairs of qualitative variables, "repulsion-attraction indices" are applied to measure the relationships (whether independent, positively correlated or negatively correlated) between the different categories of the qualitative variables.[7] Then log-linear models were estimated to identify the dependency structure between the qualitative variables. The backward selection algorithm used started with the saturated model and then removed at each step the nonsignificant interrelation terms (according to the likelihood-ratio test (Christensen 1997)). This was repeated until the simplest log-linear model was obtained, where all the dependency terms were statistically significant. Then the dependency relations indicated by the log-linear method were estimated using logistic regressions. The above exercise resulted in models for choice of "transfer type" but not "partner selection." Therefore a multiple correspondence analysis (MCA) was carried out to study the interrelations between the different categories of qualitative variables in order to obtain some insight into partner selection criteria. MCA is a generalization of "correspondence analysis" (CA) to the case of more than two qualitative variables (Hair et al. 1998). Finally the proposition on "contract design" or equity participation was tested using ANOVA analysis.

## C. *Results*

### 1. *Descriptive statistics*

The main features (the absolute and relative frequency) of each of the variables under study are given in Table II. As the table shows, a majority of the cases of collaboration (283 cases of collaboration = 84.7 per cent) is associated with firms that are not active in biotechnology. Since firms active in the biotechnology sectors are knowledge-based, it is not surprising that a majority of the firms in our sample also do not have a recognized R&D unit (274 cases of collaboration or 82.1 per cent without R&D lab). At first glance, the EU emerges as the favored region of foreign partner (65.9 per cent), followed by other countries (16.5 per cent). However it can be seen that the domination of Europe is associated with the "floriculture" sector, whose commercial output is mainly destined for the Netherlands. If floriculture collaboration is removed, the cases of collaboration with Europe decrease to 54

[7] The Repulsion-Attraction index between category $a_i$ (of $A$) and $b_j$ (of $B$) is given by $d(a_i, b_j) \equiv (n_{ij} \cdot n)/(n_i \cdot n_j)$, where $n_i$ is the number of observations where $a_i$ occurs; $n_j$ is the total number of observations where $b_j$ occurs, $n_{ij}$ is the number of observations where $a_i$ and $b_j$ both occur and $n$ is the total number of observations. If $d_{ij} = 1$, it means that categories $a_i$ and $b_j$ are independent; if $d_{ij} < 1$, it implies that categories $a_i$ and $b_j$ are repulsed and if $d_{ij} > 1$, it means that categories $a_i$ and $b_j$ are attracted. In practice, we decided to consider that categories are independent if $d_{ij}$ are in the interval [0.80, 1.20]; repulsed if $d_{ij} < 0.80$ and attracted if $d_{ij} > 1.20$. The authors are not aware of statistical tests to determine whether $d_{ij}$ is significantly close to 1 or not.

TABLE II

VARIABLES CONSIDERED IN THE TECHNOLOGY AGREEMENTS

| 334 Technology Agreements | Frequency | Percentage |
|---|---|---|
| *V1biotech*: Indian firm active in biotechnology | | |
| 1. Yes (Biotech) | 51 | 15.3 |
| 2. No (Biotech) | 283 | 84.7 |
| *V2R&D*: Indian firm with an R&D laboratory | | |
| 3. Yes (RD) | 60 | 18.0 |
| 4. No (RD) | 274 | 82.0 |
| *V3region*: Foreign partner's region | | |
| 5. NAFTA | 33 | 9.9 |
| 6. EU | 220 | 65.9 |
| 7. Asian countries | 26 | 7.8 |
| 8. Other countries | 55 | 16.5 |
| *V4sector*: Sector of origin | | |
| 9. Pharmaceuticals | 65 | 19.5 |
| 10. Chemicals[a] | 15 | 4.5 |
| 11. Agribusiness[b] | 79 | 23.7 |
| 12. Floriculture | 166 | 49.7 |
| 13. Equipment[c] | 9 | 2.7 |
| *V5type*: Transfer type | | |
| 14. Technology purchase | 141 | 42.2 |
| 15. Technology collaboration | 193 | 57.8 |
| Foreign equity participation: Mean = 19.54%, Std = 23.88% | | |

Note: Please note that nine of the cases of collaboration involved more than one sector in which case the first on the list was chosen.

[a] Chemicals include agrochemicals as well.

[b] Agribusiness includes "processed food," "food additives," "aqua-culture," "seeds," and biological "depollutants."

[c] Equipment includes medical equipment and biotech equipment.

(16.2 per cent). In the North American Free Trade Agreement (NAFTA) collaboration, the United States accounts for 31 cases of collaboration or 94 per cent of NAFTA observations. Despite colonial ties, the United Kingdom is not the dominant partner of technology agreements within the European Union: among the 220 cases of EU collaboration, only 11 are related to British partners. Collaboration in the floriculture sector also accounts for 99.2 per cent of the 100 per cent export-oriented products. Technology collaboration dominates technology purchase as the organizational option for technology transfer.

## 2. *Chi-square tests*

The chi-square tests confirmed that the relationships between all pairs of variables except between *V3region* and *V1biotech* and between *V3region* and *V5type* are statistically significant (at the 5 per cent level).[8] The nature of the relationships, as indicated by the "attraction-repulsion indices" between the various categories of any two variables, are summarized in Table III, wherever they are significant.

Let us come back to one of the original questions: what are the distinguishing features of technology cooperation of firms that are already active in the biotechnology sectors? Table III indicates that firms that are active in biotechnology and have foreign technology agreements are likely to have an R&D lab, purchase technology and *not* to be involved in floriculture. A logistic regression of *V1biotech* against *V4sector* further confirmed that the integration of biotechnology is most significant in the equipment sector and least in floriculture.[9]

The above descriptive analysis partly confirms part 1.1 of proposition 1. We see from Table III that the choice of the type of technology transfer is a function of the learning capacity of the Indian firm ($p_{ldc2}$) and the sector ($V$, $\Pi$) but not the region profile ($p_f$) unlike in the theoretical model. Part 1.3 is confirmed, as firms active in biotech and with an R&D lab are attracted to technology purchase. Usually the knowledge content in chemicals and equipment is higher than in agribusiness and therefore part 1.4 is confirmed, as technology transfer in these sectors is attracted to technology purchase while that in agribusiness is repelled by it.

Again proposition 2 is partly confirmed. As may be recalled, according to proposition 2, Indian firms prefer to collaborate with the most competent foreign firms,

[8] Chi-square tests results: Relationships between pairs of variables (significant at 5 per cent level)

| | *V1biotech* | *V2R&D* | *V3region* | *V4sector* |
|---|---|---|---|---|
| *V2R&D* | 18.44 (1) *p*-val. = 0 | | | |
| *V3region* | 5.03 (3) *p*-val. = 0.17 | 9.78 (3) *p*-val. = 0.02 | | |
| *V4sector* | 32.96 (4) *p*-val. = 0 | 104.0 (4) *p*-val. = 0 | 84.71 (12) *p*-val. = 0 | |
| *V5type* | 5.29 (1) *p*-val. = 0.02 | 26.0 (1) *p*-val. = 0 | 4.21 (3) *p*-val. = 0.24 | 23.91 (4) *p*-val. = 0 |

Notes: 1. Chi-square statistics, degrees of freedom are between brackets.
2. ☐ : Two variables are dependent.

[9] Regression *V1biot* = *f*(*V4sector*)

| | Intercept | Pharm. | Chemicals | Agribus. | Floricult. | Equip. |
|---|---|---|---|---|---|---|
| Biotech | –1.12 (0.00) | –0.17 (0.59) | 0.11 (0.82) | –0.25 (0.42) | –1.52 (0.00) | 1.83 (0.00) |
| No Biotech | — | — | | — | — | — |

–2 · log-likelihood = 257.16, sample size = 334, chi-square = 28.31, *df* = 4, *p*-value = 0.00.

This means that *Prob* (*bio*)/*Prob* (*no bio*) for Equipment is exp (1.83) = 6.23 times larger than *Prob* (*bio*) / *Prob* (*no bio*) for all the sectors (i.e., to the average effect over all the categories). We can also confirm this from the data which indicate that %*bio*/%*nobio* among Equipment = 2 while %*bio*/%*nobio* among all the sectors = 0.18.

TABLE III

SIGNIFICANT BINARY RELATIONSHIPS

| Nature of Relationship of Row with Column | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *V1biotech*: Indian firm active in biotechnology | 1. Yes (Biotech) | | | | | | | | | | | | | |
| | 2. No (Biotech) | | | | | | | | | | | | | |
| *V2R&D*: Indian firm with an R&D laboratory | 3. Yes (RD) | + | − | | | | | | | | | | | |
| | 4. No (RD) | − | | | | | | | | | | | | |
| *V3region*: Foreign partner's region | 5. NAFTA | | | + | | | | | | | | | | |
| | 6. EU | | | | | | | | | | | | | |
| | 7. Asian countries | | | + | | | | | | | | | | |
| | 8. Other countries | | | − | | | | | | | | | | |
| *V4sector*: Sector of origin | 9. Pharmaceuticals | + | | + | − | + | | + | − | | | | | |
| | 10. Chemicals[a] | + | | + | − | + | | − | + | | | | | |
| | 11. Agribusiness[b] | + | | − | | | − | + | | | | | | |
| | 12. Floriculture | − | | − | | − | | − | + | | | | | |
| | 13. Equipment | + | − | + | − | + | − | + | − | | | | | |
| *V5type*: Transfer type | 14. Technology purchase | + | | + | | | | | | | + | − | | + |
| | 15. Technology collaboration | − | | − | | | | | | | | + | | − |

+ : Attraction between the two categories. − : Repulsion between the two categories.
 : No relation between the two categories.

namely, those from the United States or EU, while foreign firms prefer to collaborate with Indian firms that have an R&D lab or are otherwise active in biotech. From Table III, it can be seen that Indian firms with an R&D lab are attracted to firms from NAFTA and Asian countries but not EU. This indicates a contradiction between the theoretical and empirical models because the EU is a knowledge-rich region comparable to NAFTA. Moreover, it also reveals that "geographical" and "cultural" proximity could play a significant role in the evaluation of competence because Asian firms are perceived to be equivalent to NAFTA firms and preferred to EU firms by R&D-intensive, i.e., knowledge-rich Indian firms. Finally, Table III implies that the partner selection criteria are linked to some form of regional "comparative advantage" of foreign firms according to the sector concerned. In the most high-tech areas of chemicals, pharmaceuticals and equipment sectors, NAFTA is the favored partner. Asian firms are also preferred in high-tech sectors such as pharmaceuticals and equipment but not in chemicals. However they are also preferred to NAFTA in agribusiness. EU is the shunned partner in agribusiness and equipment. Other countries take up the slack in chemicals and floriculture (in floriculture it is mainly Israel).

3. *Log-linear models*

Starting from the saturated log-linear model where all the variables—*V1biotech*, *V2R&D*, *V3region*, *V4sector*, and *V5type*—are mutually related, a backward elimination algorithm identified the appropriate dependency structure for our data. Elimination of nonsignificant dependencies between the variables was based on the likelihood-ratio chi-square test (Christensen 1997). The best log-linear model for our data was described by the following dependency structure:

$$\mathrm{Log}(V1, V2, V3, V4, V5) = \mu + \lambda(V1 \cdot V2 \cdot V5) + \lambda(V4 \cdot V5) + \lambda(V2 \cdot V4) + \lambda(V1 \cdot V4) + \lambda(V3 \cdot V4).$$

This gave us five dependency relations to consider as given below:

- 1st dependency: *V1biotech · V2R&D · V5type*,
- 2nd dependency: *V4sector · V5type*,
- 3rd dependency: *V2R&D · V4sector*,
- 4th dependency: *V1biotech · V4sector*,
- 5th dependency: *V3region · V4sector*,
- Likelihood-ratio chi-square = 105.24802, $DF = 121$, $p$-value = 0.845.

The null hypothesis tested here was: "The eliminated dependencies: *V1biotech · V3region*, *V2R&D · V3region*, *V3region · V5type*, *V1biotech · V2R&D · V3region*, etc. are not significant," i.e., eliminating them from the log-linear model will not significantly reduce the quality of these models. Since the $p$-value was greater than 0.05, the null hypothesis was not rejected (at the 5 per cent level) and the simplified model proposed was not significantly worst than the saturated initial model (where all the variables are mutually related).

As can be noted, there is only one three-factor effect: *V1biotech*, *V2R&D*, and *V5type* are three mutually dependent factors. *V4sector* is related to all of the four other variables. *V3region* is independent of *V1biotech*, *V2R&D*, and *V5type*. *V3region* depends only on the sector of activity *V4sector*. Thus the log-linear model results coincide with the binary (chi-square) results, except for the relationship between *V2R&D* and *V3region* which was found to be significant by the chi-square test, but is not considered to be significant by the log-linear analysis (this is likely to be due to the fact that these two methods use two different statistical tests).

The log-linear models partly confirm part 1.1 of proposition 1 and propose two types of models for the choice of type of technology transfer. Either choice is a function of the competence of the Indian partners or a function of the sector in which the collaboration is embedded, but it is not determined by the competence of the foreign firm (i.e., assuming that our indicator of "regional location" is a good measure of a foreign firm's competence). The logistic regressions that estimate these two models are given in Table IV.[10]

[10] For instance model 1 corresponds to the functional form:
$Prob(tech.purchase)/Prob(collaboration) = \exp(-0.016 - 0.68 \cdot Z(bio \cdot R\&D))$,

TABLE IV

MODELS OF CHOICE OF TYPE OF TECHNOLOGY TRANSFER

A. Model 1 of choice of type of technology transfer

| | Intercept | *V1biotech · V2R&D* |
|---|---|---|
| Purchase | –0.016 | –0.68 |
| Collaboration | — | — |
| *p*-value of predictors | –0.90 | 0.00 |

–2 · log-likelihood = 426.09, sample size = 334, chi-square = 28.8, *df* = 1, *p*-value = 0.00.

B. Model 2 of choice of type of technology transfer

| | Intercept | Pharmaceuticals | Chemicals | Agribusiness | Floriculture | Equipment |
|---|---|---|---|---|---|---|
| Purchase | –0.03 | 0.00 | 0.16 | –1.34 | –0.09 | 1.28 |
| Collaboration | — | — | — | — | — | — |
| *p*-value of predictors | –0.89 | –0.99 | –0.72 | 0.00 | –0.70 | 0.00 |

–2 · log-likelihood = 429.49, sample size = 334, chi-square = 25.40, *df* = 4, *p*-value = 0.00.

The first model computes *V5type* as a function of *V1biotech* and *V2R&D*. This model is obtained by eliminating nonsignificant (using likelihood-ratio chi-square test) covariates from the saturated model *V5type* = *V1biotech* + *V2R&D* + *V1biotech* · *V2R&D*. The interaction covariate, denoted hereafter by *Z*(*bio* · *R&D*), takes the value 1 if the studied cooperation is related to an Indian firm with neither a biotechnology activity nor an R&D lab; it takes the value –1 if the Indian firm has a biotechnology activity or/and an R&D lab. This interaction term was suggested by the examination of *V5type* frequencies within the four firms classes: (bio, R&D), (bio, no R&D), (no bio, R&D), and (no bio, no R&D).[11]

In Table IV, and in model 1, a *p*-value less than 0.05 indicates that the model with the predictor *V1biotech* · *V2R&D* is significantly better than the model containing only a constant. The figures in the brackets represent the *p*-value of the predictors. Here a *p*-value greater than 0.05 indicates that the related predictor is not significant.

where *Z*(*bio* · *R&D*) = 1 for (no Biotechnology and no R&D lab) firms and *Z*(*bio* · *R&D*) = –1 for (Biotechnology or/and R&D lab) Indian firms. This in turn means that firms active in biotechnology or/and having an R&D lab are more likely to buy than collaborate as compared to firms without biotechnology activity and R&D laboratory. The other logit models have to be interpreted similarly. In the logit model we can choose the reference category either as one of the categories of the variable, or as the average behavior of all the categories. We have taken the latter approach.

[11] Using a correspondence analysis for the relationship between *V5type* and an interaction variable with four categories (bio–R&D, bio–no R&D, no bio–R&D, no bio–no R&D), we found that the main interaction effect was due to the difference between firms without bio and R&D (low technology firms) and firms with bio or/and R&D (high technology firms). Therefore, the interaction covariate was introduced using the variable *Z*(*bio* · *R&D*).

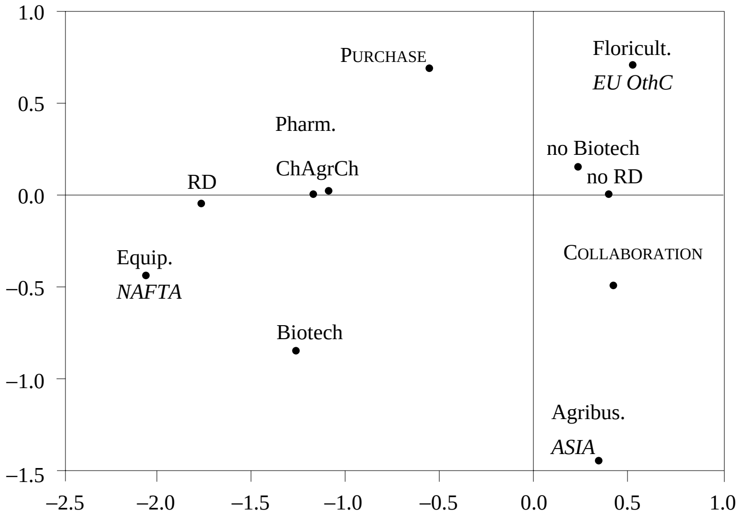
Thus we find that the technology transfer type mainly depends on whether the Indian firm belongs to the (no biotechnology and no R&D lab) or (biotechnology or/and R&D lab) group. Model 1 indicates that when an Indian firm has a biotechnology activity or/and a R&D lab, it increases the odds of "buying technology" vs. "entering into a collaboration" by $e^{(2\times 0.68)} \approx 4$ times. In other words, {probability of purchase / probability of collaboration} is four times higher for an Indian firm active in biotechnology or/and having an R&D lab than for one with neither biotechnology activity nor R&D lab. Thus this model confirms part 1.3 of proposition 1 according to which learning capacities of ldc firms indicated by their biotechnology and R&D activities are more favorable for technology purchases than technology collaboration.

Similarly interpreting the second model, we see that the choice of the type of transfer is essentially determined by the involvement in the equipment and agribusiness sectors. Furthermore, the model indicates that the {probability of technology purchase/probability of collaboration} for equipment is $e^{1.28}$, i.e., 3.60 times higher than that for all the sectors taken together. However the {probability of technology purchase/probability of collaboration} for agribusiness is only $e^{-1.34}$ times or 0.26 times (i.e., smaller) that for all sectors taken together. This seems to confirm part 1.4 of proposition 1. Now equipment is the sector in which most of the developing countries are much less advanced than the firms of developed countries. The most sophisticated equipment is seldom available in developing countries through domestic firms. Therefore for an Indian firm, the sector of equipment embodies a high knowledge value "*V*" which favors technology purchase rather than collaboration. In contrast, since agribusiness is a sector in which India is strong, the knowledge value of foreign technology is not very high compared to other sectors and therefore the probability of technology purchase is lower than that for other sectors. For the other sectors, the ratio of probabilities is not significantly different from that for the entire sample.

### 4. *Multiple correspondence analysis (MCA)*

It can be seen that the log-linear model does not reveal any statistically significant model of partner selection, but indicates that the choice of the foreign partner is linked to sectors. Therefore either proposition 2 is not confirmed by the log-linear model or "region" is not the best indicator of $p_f$. Assuming the former, we conducted an multiple correspondence analysis (MCA) in order to examine the comparative advantage of each region and criteria for partner selection. Using the results of the log-linear model, we first ran an MCA on *V1biotech*, *V2R&D*, *V4sector*, and *V5type* followed by a "correspondence analysis" (CA) on *V3region*, and *V4sector*, instead of using an MCA on all the five variables. This could be justified by the fact that, according to the log-linear model, *V3region* depends only on *V4sector*, and therefore an MCA on *V1biotech*, *V2R&D*, *V4sector*, and *V5type* and a separate CA

Fig. 3. Partner Preference (MCA Results)




Note: Ch: chemicals, AgrCh: agrochemicals, OthC: other countries.

on *V3region* on *V4sector* would yield better MCA results. The final result is given in Figure 3. The discrimination measure table indicates that axis 1 is strongly related to categories of R&D and sector while axis 2 is related to the sector and type of transfer.

The MCA graph indicates that NAFTA is more likely to engage in technology transfer with an Indian firm that has an R&D laboratory or is involved in biotechnology, thus supporting proposition 2. The European Union and other countries are more likely to engage in technology transfer with a firm that does not have an R&D lab or is not involved in biotechnology. Asia does not have any partner preferences. The MCA graph also indicates that the comparative advantage of NAFTA is equipment, that of Asia is agribusiness and that of the EU is floriculture. Other countries have no clearly defined sectoral preference.

## 5. *ANOVA analysis*

Finally, we analyze proposition 3 on foreign equity participation. This was tested by running an ANOVA analysis the results of which are given in Table V. The ANOVA analysis tested the null hypothesis according to which the foreign equity participation was not significantly different in the different categories of the relevant variables. The null hypothesis was always rejected. Furthermore, the results seem to confirm proposition 3. Foreign partners invest less in Indian firms whose knowledge needs and knowledge base are weak than otherwise. The NAFTA firms are most willing or interested to invest in Indian ventures, followed closely by Asian

TABLE V

ANOVA RESULTS ON CONTRACT DESIGN

| | Significance with Respect to Fisher Test (at 5% level) *p*-value | Mean Foreign Equity Participation |
|---|---|---|
| *V1biotech* | 0.00 | |
| Not involved in biotech | | 31.4% |
| Involved in biotech | | 52.7% |
| *V2R&D* | 0.00 | |
| Not having R&D lab | | 32% |
| Having R&D lab | | 52.4% |
| *V3 Region* | 0.00 | |
| Other countries | | 27.6% |
| EU | | 31.7% |
| Asia | | 45.8% |
| NAFTA | | 50% |
| *V4Sector* | 0.00 | |
| Floriculture | | 21% |
| Equipment | | 38.5% |
| Chemicals | | 41.4% |
| Agribusiness | | 43.9% |
| Pharmaceuticals | | 47.3% |

firms. Again, it points out that the positioning of EU does not conform to that of a rational play, as it is a knowledge-rich region but exhibits a considerably lower foreign equity participation than NAFTA. Foreign equity participation is also an increasing function of the complexity of the technology involved. The knowledge content in floriculture is lower than in agribusiness and here the foreign equity participation is also lower, confirming our theoretical model. Again, with respect to traditional manufacturing sectors like pharmaceuticals, equipment, and chemicals, the tacit knowledge involved in independently developing innovations in pharmaceuticals is higher, which is also reflected in the higher foreign equity participation. This could be either due to the fact that the complexity of the technology increases the costs of commercialization, forcing the foreign partner to assume more of the risk, or it could also mean that such sophisticated products or processes are scarcer in India and may therefore yield higher returns.

## V. CONCLUSIONS: POLICY RECOMMENDATIONS AND POSSIBLE EXTENSIONS

Miller, Glen, Jaspersen, and Karmokolias (1997) point out that the incentives for North-South inter-firm collaboration lie in the scarcity and complementarity of assets, resources, and competence that can be pooled together in a collaboration. "Local partners bring knowledge of the domestic market; familiarity with Government bureaucracies and regulations; understanding of local labor markets; and possibly existing manufacturing facilities. Foreign partners can offer advanced process and product technologies, management know-how, and access to export markets" (p. 26). Assuming that such complementarities exist for inter-firm cooperation between Indian and foreign firms, this paper studied the strategic foundations that sustained international cooperation in the Indian biotechnology sectors. An original feature of this paper in terms of methodology was the construction of a game theoretical model that embodied the behavior of Indian and foreign firms as rational players and the verification of this model with real data. This enabled us to examine whether the observed actions were motivated by rationality, or whether they emerged due to market imperfections, given the constraints imposed by the model considered.

The game theoretical model of technology transfer yielded three propositions to be tested. There is no technology transfer if neither a technology purchase nor a collaboration increases the final profit of the local firm. However technology transfer is possible with the maximum or minimum of asymmetry in the technological competencies of the local and foreign firms. Whenever feasible, the type of transfer chosen depends on the learning capacity of the local firm, technological competence of the foreign firm, and the sector targeted. Collaboration is preferred to purchase whenever the technological competence of the foreign firm is high, the learning capacity of the local firm is low or the ratio of value of knowledge to the market size is low. Thus the theoretical model clearly defined the strategic foundations of the different types of technology transfer as a function of the technological competence of the firms involved.

Then these theoretical propositions were tested on data pertaining to technology transfer in the Indian biotechnology sectors. The empirical analysis revealed that the theoretical model could better predict the determinants of "choice of type of technology transfer" and "contract design" for equity participation than the criteria for "partner selection." The inadequacy of the theoretical model lay in its consideration of the "partner selection" criteria in terms of the incentives for cooperation generated by the competence of the two firms. In reality, "partner selection" seems to be a more complex process, being a function of geographical and cultural proximity as well as the comparative advantage of certain countries in certain sectors. Some of these contradictions could also have been due to the fact that we did not have adequate data on the competence of the foreign firms.

Combining the results of the theoretical model on technology transfer and the empirical model on partner selection, the following recommendations can be inferred for policy formulation: (i) both Europe and India should consider to improve the circulation of information (in terms of firm competence and possibility for cooperation) with respect to one another; (ii) international technological cooperation can be promoted by increasing the "learning capacity" of Indian firms; (iii) there must be government aid not only for the development of agribusiness-related technologies but also generic technologies such as equipment.

The above study reveals that the strategic positioning of European firms does not correspond to that of a knowledge-rich region comparable to NAFTA. This was demonstrated in the various analyses on transfer type, partner selection criteria or contract design. Therefore European firms and governments must reflect on whether the present strategic positioning of EU firms can be justified on the basis of profit evaluation or whether it is due to inefficient circulation of relevant information on Indian firms and markets. The same holds for Indian firms and the Indian government with respect to efficient diffusion of information on the potential for cooperation with European firms.

With respect to the strategy of Indian firms, the study reveals (confirming the theoretical model) that Indian firms with a strong learning capacity prefer to buy technology rather than initiate a strategic collaboration. Since firms involved in the biotechnology sectors tend to be knowledge-intensive, it indicates that biotech firms are more likely to buy technology rather than enter into a foreign collaboration. Furthermore, the theoretical model points out that foreign firms with a high technological competence prefer to initiate a strategic collaboration with local partners that are weak in terms of technological competence but are capable of learning. Though this point could not be confirmed by the empirical model, as we did not have an indicator of the original competence of ldc firms, it should be kept in mind while trying to promote international strategic alliances.

The asymmetry in terms of knowledge between Indian and foreign firms (as indicated by the ranking of sectors according to the significance of integration of biotechnology through foreign collaboration) seems to be highest in the equipment sector and lowest in floriculture. So far the Government of India has mostly given priority to the creation of knowledge and competence in the agricultural and agribusiness sectors. However given that equipment is a generic technology that is essential to a number of sectors, it must take measures to reduce the lag in technological knowledge in this sector as well.

Since the used database did not include information on firms in the biotechnology sectors that had not entered into foreign collaboration, we could not attempt to give a complete answer to the question: can technological collaboration with the rest of the world constitute a potential vehicle for the integration of biotechnology in the production systems of Indian firms? However, the very fact that only a marginal proportion of the firms involved in foreign collaboration are active in biotechnology, suggests that foreign technology agreements are not an effective vehicle for the integration of biotechnology in India.

A number of possible extensions can be envisaged. In terms of the empirical investigation, the database on Indian firms in the biotechnology sectors can be expanded to include Indian firms that did not initiate technology transfer and construct better indicators of technological competence of the Indian and foreign firms to test the theoretical propositions. In terms of the theoretical model, the impact of the change in the order of play in the game could be examined, so that the local firm does not enjoy first mover advantages. This analysis assumed that moral hazard was absent. However, it remains to be determined whether the incorporation of moral hazard is likely to reinforce propositions 1 and 2. It is well known that the presence of moral hazard reduces the incentives for technology transfer, which is one of the main reasons for fewer North-South technology transfers compared to North-North technology transfers. Thus it would be interesting to study the possible solutions for reducing the moral hazard. In particular, this deals with the subtle issue of intellectual property rights enforcement, which should be addressed more thoroughly in future theoretical and empirical work, as well as in policies aimed at providing incentives for new technology integration.

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