Technology Cooperation between Firms of Developed and Less-Developed Countries

By

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ABSTRACT

The paper presents a game theoretic model of technology cooperation where a developing country firm has the options of either developing an innovation alone, purchasing information or collaborating with a developed country firm. Technology cooperation changes the probability of success of commercialization.

Technology Cooperation between Firms of Developed and Less-Developed Countries[1]

Most developing countries consider foreign investment and international technology transfer as important means of acquiring knowledge from the rest of the world. Therefore, the economic literature on this subject mainly focuses on what kind of technology, obsolete vs. new, is likely to be transferred (Marjit, 1988) or how government or industrial policy should be formulated to maximize the returns to knowledge acquisition from foreign investment (Svejnar and Smith 1984; Marjit, 1995). The strategic foundations of cooperation between firms of *developed countries* (or DC) and firms of *less developed countries* (or LDC) themselves have been rarely modeled. One paper that considers the incentives for technology transfer in a non-cooperative set up is Marjit (1990) where a foreign firm transfers technology and then competes with the local firm because collusion is not possible. However, technology transfer is often the result of the creation of a joint venture and rarely does a foreign firm sell a technology to a local firm and enter the local market immediately afterwards.

Furthermore, in game theoretic R&D cooperation models, innovations can be created either through in-house development or cooperation with other firms. In other words, firms cannot buy "information" relating to the innovation because the knowledge or artifact to be created is assumed to be unknown at the time being considered. However this is not the case when an innovation is launched in a LDC market through an international technology transfer. Thus the objective of this paper is to present a simple game theoretic model of technology cooperation between DC and LDC firms where they can choose between "technology purchase" and "collaboration" and to examine the following questions:

- Under what conditions will a LDC firm choose to cooperate with a DC firm?

- If cooperation is chosen, under what conditions will "technology purchase" take place and under what conditions will "collaboration" take place?

- What are the criteria for partner selection i.e. what is the level of asymmetry of technological competencies that can be tolerated in any form of cooperation?

- In a collaboration, what determines the proportion (equity proportion) in which the revenue generated is shared between the two firms?

Consider a LDC firm and a DC firm that can possibly engage in technology cooperation. The DC firm has knowledge that is deemed to be worth *V* by both firms. The LDC and DC firms are characterized by their firm specific technological competence as given by the probability of successfully commercializing the innovation associated with V in the LDC market. Let the profit associated with the *successful* commercialization of *V* in the LDC market be *Π*. Then technology transfer can be examined as a sequential game where the LDC firm first chooses whether or not to solicit the DC firm, and the DC firm agrees (i.e. says "yes") or refuses (i.e. says "no") when solicited. If the DC firm agrees then the two firms negotiate certain variables that determine the division of expected profit. Then the game ends.

As the first player, the LDC firm has three strategies by which it can try to create the innovation associated with the knowledge base *V*; either through "internal R&D", or a technology "purchase" or a technology "collaboration". The latter two represent the two organizational options under which the LDC and DC firms can cooperate.

Let p_{ldc1} be the probability that the LDC firm independently develops the innovation without cooperation with the DC firm. Thus p_{ldc1} represents the existing technological competence of the LDC firm. Now the LDC firm can also buy the information associated with *V* in the form of a tangible product such a license or a blueprint. However, under a technology purchase the entire risk of creating or redesigning the innovation to the conditions of the LDC market is borne by the LDC firm. From the point of view of the DC firm, if it sells the license or blue print for a price *P*, it gains *P* and if it does not sell the license it gains 0. Whenever the LDC firm obtains information from a DC firm, its technological competence changes and the probability of success of the LDC firm becomes p_{ldc2}. Thus p_{ldc2} can be viewed as the learning capacity of the LDC firm.

Finally, the LDC firm can solicit a DC firm to collaborate. In this case, the LDC firm does not buy anything. It invites the DC firm to invest its knowledge *V* and create the innovation suited to the LDC market jointly with the LDC firm. In return, the LDC firm offers to share the profit generated from the innovation, the proportion $(1-\alpha)$ going to the DC firm where $\alpha \in (0,1)$. This time, from the point of view of the DC firm, if the DC firm says "yes", it can gain $(1-\alpha)$ of the expected profit; and if it says "no", it can try to invest its knowledge V in some other collaboration. Thus α, $(1-\alpha)$ can be taken as the equity participation of the LDC and DC firm respectively in the joint venture. Let p_{dc} be the probability of the DC firm of successfully "re-designing" the innovation to the conditions of the LDC market alone. Assuming that p_{ldc2} and p_{dc} are independent, and there is no problem of moral hazard, the probability of success of the joint venture is $(1 - (1 - p_{ldc2}) \cdot (1 - p_{dc}))$ or $(p_{ldc2} + p_{dc} - p_{ldc2} \cdot p_{dc})$. Thus the technological competence of the joint venture is higher than the probability of success of both the LDC firm after purchase of information p_{ldc2} and the DC firm p_{dc}. This reveals that 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.

In the case of a technology "purchase" the firms then negotiate the price of the technology *P*. In the case of a "collaboration" they negotiate the proportion α in which the profit generated *Π* is to be shared. In order to resolve the negotiation problem, we consider the simplest game theoretic solution namely the Nash bargaining solution. The disagreement points are taken to be the payoffs associated with the players when the DC firm says "no" on being solicited by the LDC firm and they are different under the two options for the DC firm as explained above.

Let π_{ldc}, π_{dc} be the payoffs to the LDC and DC firm respectively and let α be the share of *Π* going to the LDC firm. Recall that the negotiated price *P** is the solution to equation (1) and the negotiated share of the LDC firm α^* is the solution to equation (2):

$$\underset{\{P\}}{Max}(p_{ldc2}.\Pi - P - p_{ldc1}.\Pi).P \qquad (1)$$

$$\underset{\{\alpha\}}{Max}[(\alpha.(p_{ldc2} + p_{ldc1} - p_{ldc1}.p_{ldc2}).\Pi) - (p_{ldc1}.\Pi))].[((1-\alpha).(p_{ldc2} + p_{ldc1} - p_{ldc1}.p_{ldc2}).\Pi) - V] \qquad (2)$$

This gives us:

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

$$\alpha* = \frac{\Pi(p_{ldc2} + p_{dc} - p_{ldc2} \cdot p_{dc} + p_{ldc2}) - V}{2.\Pi.(p_{ldc2} + p_{dc} - p_{ldc2} \cdot p_{dc})} \qquad (4)$$

We thus get the following payoff structure after negotiation (also given in figure 1).

When the LDC "commercializes alone": { $\pi_{ldc} = p_{ldc1}.\Pi$; $\pi_{dc} = 0$ }.

When the LDC and DC firm cooperate through a "technology purchase":

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

When the LDC and DC firm cooperate through a "collaboration":

{ $\pi_{ldc} = (((a + p_{ldc1}).\Pi) - V)/2$; $\pi_{dc} = (((a - p_{ldc1}).\Pi) + V)/2$ }.

Four assumptions are made for the resolution of the model:

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

A2: There is no moral hazard from either the DC or LDC firm. The DC firm has no incentive to commercialize the innovation alone in the LDC market i.e. $p_{dc}.\pi < V$ and the LDC firm cannot resell the technology to any other firm or sell the product outside of the LDC market.

A3. Information has positive value i.e. $p_{ldc2} > p_{ldc1}$

A4. The LDC firm starts the game.

The first and second assumptions are made for simplification of the game in order to focus on the partner selection problem and incentives for cooperation. The third assumption ensures that learning from purchase of information is positive. The fourth assumption reflects the reality of international R&D alliances where the uncertainty is related to the market rather than the technology and better known to the local partner. Any of the above assumptions can be removed in further extensions and such removal is likely to change the results. The Nash equilibrium for this game is found by backward induction and the following results can be derived subsequently.

Comment: (i) For a LDC firm "commercializing alone" is a dominated strategy.

 (ii) For a DC firm, if a LDC firm offers to buy technology, saying "no" is a dominated strategy.

Proof: These follow from the assumptions and the payoff structure resulting from the negotiations on P and α.

Proposition 1:

(1.1) Contract type: Let C^{buy} represent the set of (p_{ldc2}, p_{dc}) under which the LDC firm will buy from the DC firm and let C^{collab} represent the set of (p_{ldc2}, p_{dc}) under which the LDC and DC firm will collaborate. These are represented in figure 2 for the case when C^{collab} is non-empty.

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

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

Corollary: C^{collab} is non-empty if and only if $V \leq \Pi$.

(1.2) Partner selection: In a technology purchase: $\dfrac{d\pi_{dc}}{dp_{ldc1}} < 0, \quad \dfrac{d\pi_{dc}}{dp_{ldc2}} > 0, \quad \dfrac{d\pi_{ldc}}{dp_{dc}} = 0.$

In a collaboration: $\dfrac{d\pi_{dc}}{dp_{ldc1}} < 0, \quad \dfrac{d\pi_{dc}}{dp_{ldc2}} > 0, \quad \dfrac{d\pi_{ldc}}{dp_{dc}} > 0$.

(1.3) Contract design: In a collaboration: $\dfrac{d\alpha}{dp_{ldc1}} > 0 \quad \dfrac{d\alpha}{dp_{ldc2}} < 0 \quad \dfrac{d\alpha}{dp_{dc}} < 0 \quad \dfrac{d\alpha}{dV} < 0$

$\dfrac{d\alpha}{d\Pi} > 0$.

The proofs are obvious. Part (1.1) can be derived from the fact 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). Therefore the LDC firm buys whenever the payoff from "purchase" is higher than that from "collaboration" given that the foreign firm says "yes" and whenever the foreign firm is likely to say "no" to the collaboration.

Though this game is between two firms, let us imagine a situation just before the beginning of the game, where a LDC firm has to target a foreign partner or a situation where a foreign firm is confronted with a solicitation from more than one LDC firm. How will they choose their partner? This problem can be resolved by noting the impact of the different competencies on the payoffs under the two forms of cooperation. Thus part (1.2) is found by taking the appropriate derivatives of the payoffs after substituting for the Nash bargaining solution of P and α.

Then part (1.3) is obtained by taking the derivatives of α^* obtained in equation (2).

Thus even from this simple model, we can obtain some insight on the strategic foundations of cooperation between DC and LDC firms that have not been highlighted in the literature:

(i) *From the viewpoint of a DC firm:* Unlike in papers mentioned earlier, our model shows that a DC will be willing to cooperate in transferring even non-obsolete or state of the art technology to a LDC firm if rents can be earned. Under both technology transfer, and collaboration the bargaining power of the *DC* firm increases with higher p_{ldc2} and lower p_{ldc1}. Therefore a *DC* firm will prefer to partner with the LDC firm with the highest p_{ldc2} or lowest p_{ldc1}. For a sufficiently high level of technological competence p_{dc}, a *DC* firm will never sell to a LDC firm, preferring to seek a LDC partner to collaborate with in the LDC market.

(ii) *From the viewpoint of a LDC firm:* Since a *LDC* firm bears all the risks and enjoys exclusive industrial rights over the innovation in a technology transfer, 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 acquisition of information, i.e. if p_{ldc2} is high enough. If a *LDC* firm enters into a collaboration, it will prefer to partner with the most competent *DC* firm, i.e. with the highest p_{dc}.

(iii) *Determinants of collaboration:* The region of collaboration increases when the technology is more outdated or less complex (i.e. for lower *V*) or when the market value of the innovation is higher (i.e. high *Π*). Any level of asymmetry of competencies can be

tolerated (supposing that only such partners were available) being adjusted through the

nature of the contract chosen ($(p_{ldc2} = 1, p_{dc} = 0) \in C^{buy}$) and

$(p_{ldc2} = 0, p_{dc} = 1) \in C^{collab}$). The region of collaboration is determined by the

learning capacity of the *LDC* firm (p_{ldc2}) and not its original technological competence

(p_{ldc1}). The equity participation of the DC firm increases with the learning capacity of the

LDC firm and the knowledge content of the technology; but it decreases with the

magnitude of profit that can be earned in the LDC market and the original technological

competence of the LDC firm.

References

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Figure 1: Game of ldc and dc firm cooperation

$a= p_{ldc2}+p_{dc}-p_{ldc2}.p_{dc}$

The vectors in the boxes represent payoffs after negotiation

Figure 2: Domain of cooperation