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LICENSING, IMITATION AND SUBSIDIARY UNDER GOVERNMENT POLICY UNCERTAINTY

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Abstract: This paper considers an infinite period model to analyse the impact of future liberalisation policy on the quality of international technology transfer by a Multinational Corporation (MNC). The domestic government policy, either protection or liberalisation, is uncertain. It shows a non-monotonic relationship between the quality of the technology transferred and the belief about the future liberalisation policy under certain parameter configurations. The imitation of foreign technology by a host firm is treated as a choice variable and is shown to occur in equilibrium. As a result, it is found that the MNC and the host firm may compete with the same technology in the domestic market. This approach thus provides an endogenous theory of evolution of market structure.

Key words: Licensing, imitation, quality of technology, subsidiary, policy uncertainty.
JEL Classification Number: F23, O38, L13.

1. INTRODUCTION

The literature provides a number of reasons for the existence of multinational corporations (MNCs). Dunning's (1977, 1981) "eclectic" theory, based on the "ownership", "locational" and "internalisation" (OLI) advantages, has turned out to be the predominant school of thought today on this topic. Ownership advantage consists of some product or production process which the other firms do not have, such as a patent, blueprint, trade secret and even a trademark or reputation. These advantages give a firm competitive edge over other firms to do business abroad. The "locational" advantage simply dictates that the production should be undertaken in the foreign country rather than producing at home and exporting it to the foreign market. The obvious sources of this advantage are tariff, quota, transport costs and cheap factor prices. The importance of the "internalisation" lies in the fact that even if a firm has "ownership" and "locational" advantages it can sell the blueprints or technology at 'arm's length' to a potential

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host country firm rather than setting up a production facility there. Whether a transaction should be internalised is basically a matter of cost associated with the exchange of information between agents. Rugman (1986) argues that the theory of internalisation plays a central role in explaining the existence of MNCs. The problem with the 'arm's length' transfer of technology mainly arises from the pricing and the risk of dissipation of this firm specific advantage. In this paper we focus on the 'internalisation' aspect of technology transfer by highlighting the problem of imitation by the host firm, in the absence of a long term enforceable contract.

The literature on internalisation has focussed on the problem of technology transfer in a situation where a firm can internalise the transaction and set up a subsidiary at some costs (Buckley and Casson (1976), Caves (1982), Dunning (1981), Rugman (1981), Teece (1981) etc.). Thus, the theory has provided the choice between licensing and setting up of a subsidiary by an MNC, depending on their relative costs. However, the situation in most developing countries is quite different, where the MNCs may not be allowed to set up a subsidiary any time they want to because of government restrictions. This happens when the host government pursues a deliberate policy of technology import by the domestic firm with the view that technology import may give rise to some kind of externality in developing the domestic technological capabilities in early stages of development. However, at some later stage the economy may be liberalised to allow for the setting up of subsidiaries by the MNCs. For simplicity, we consider only two kinds of policies the government might undertake. (1) **Protection**: when the government encourages the licensing of technology from foreign firms but does not allow any equity participation by the foreign firms in the domestic business and (2) **Liberalisation**: when the government allows the setting up of a wholly owned subsidiary by an MNC.[1]

We consider an infinite period model. In each period the government of the host country undertakes either one of the above two policies. We assume that the first period starts with the policy of protection. As a result, the MNC can only license out its technology in the first period. However, the MNC may be allowed to set up a (wholly owned) subsidiary in the future. Thus, we allow for the possibility of uncertainty in government policy, in the sense that the economy will be liberalised in the next period with some positive probability.[2] Once the state of the economy is liberalised, it is assumed that it would remain so forever. We are ruling out the reversion of government policy once adopted, as certain decisions like investments etc. are irreversible/sunk in nature.

[1] This kind of government policy reform, i.e., a move from protection to liberalisation, is a typical feature of development strategy in many developing countries, such as India.

[2] Usually the governments in the developing countries open up their economy gradually rather than at one go. In other words, the government first moves from its protectionist regime to a partially liberalised regime (where MNCs are allowed to hold only a partial ownership in the domestic business) and from there to full liberalisation (where the wholly owned subsidiaries are also allowed). There is always uncertainty about the transition to a subsequent stage of the liberalisation process. However, in this paper we focus on the simplest possible liberalisation policy, i.e., a shift from a regime of protection to full liberalisation. See Sinha (2001) on the joint venture instability in the context of liberalisation from partial to a full liberalisation.

There are two firms: an MNC and a host firm. Here the modes of technology transfer include licensing and setting up a subsidiary. The MNC has two different technologies in terms of quality (i) superior technology and (ii) inferior technology. However, when these technologies are transferred there is a problem of imitation as the host firm can imitate through a process of "learning by doing" in one period, at a fixed cost. Whether the host firm does incur that cost or not, that remains a choice variable. In this framework we are interested in analysing the impact of uncertainty in liberalisation policy on the quality of technology transfer by the MNC and the subsequent evolution of market structure. We assume that the two parties cannot write any enforceable long term contract on technology transfer and on payments.[3] In the absence of long term contract the MNC, in our model, would charge the upfront payment if it supplies a technology. Also we do not allow for any royalty payment[4] in our analysis.

In the absence of long term contract, we argue that the inferior technology would serve two purposes. (i) It would affect the imitation incentive of the superior technology if it is transferred later, and (ii) when the MNC wants to wait for liberalisation to take place in future, in the meantime, it could transfer the inferior technology to get some payment. We characterise the optimal strategy of the MNC depending on the parameters of our model. We find a non-monotonic relationship between the quality of the technology transferred and the belief about the future liberalisation. Also we focus on the evolution of the market structure consequent upon the technology transfer. The imitation of the foreign technology is shown to occur in equilibrium; and as a result, it is found that the MNC and the host firm may compete with the same technology in the domestic market. The approach, thus, provides an endogenous theory of evolution of market structure. In addition, it is shown that the best technology may not be transferred in the first period even if the MNC is never allowed entry into the domestic market.

Now we relate our paper with the existing literature. The uncertainty regarding government policy is noted, among many others, in Buffie (1995), Kabiraj and Yang (2001), Rodrik (1989). Rodrik (1989) noted that one source of credibility problem in government policy is incomplete and asymmetric information. Private investors may not know the true objective function of the government in power, or may confuse it with the alternative government whose objectives differ. Imperfect information is particularly likely to be prevalent in many developing countries where governments rotate frequently. Thus the private investors would not know for sure whether the economy will be liberalised so that foreign firms are allowed to set up subsidiaries. Also Kabiraj and Yang (2001) have discussed about the political uncertainty that usually prevails in the developing countries on the issue of liberalisation.

[3] Regarding the assumption of non-enforceability of long term contract we have some evidence in the Indian context. Desai (1988) noted that "the difficulty of getting approvals for agreement lasting more than five years prevents the long term exploitation of the market through licenses" (pp. 168). The renewal of licenses was officially discouraged.

[4] These behaviours are not out of place in the Indian context. In India royalty rates were restricted to low levels generally around 3–5%. As a result of this low royalty rate there is evidence that these rates have been counterbalanced by higher lump sum payments (Alam, 1985).

In the context of technology transfer there are two kinds of explicit treatment of imitation available in the literature: (i) costless imitation and (ii) costly imitation. In case of costless imitation, the imitation occurs once the technology is transferred, and so it is not a choice variable (Katz and Shapiro (1985), Kabiraj and Marjit (1993) etc.). An explicit treatment of costly imitation is available in Rockett (1990), where she has extended the licensing literature to allow the licensor to choose the "quality" of the licensed technology as well as "the structure of payments" for the licence. The product market is characterised by Cournot competition and both the licensor and the licensee compete in the same market. In her paper, the nature of the contract is such that imitation becomes unprofitable in equilibrium. Gallini and Wright (1990) have considered the problem of technology transfer under asymmetric information when sharing of pre-contractual information about the economic value of innovation facilitates imitation at a fixed cost. However, in Gallini and Wright (1990) also, imitation does not take place in equilibrium. Contrary to the existing literature, in our paper, the superior technology is transferred even though the imitation takes place in equilibrium.

This paper is related to a paper by Ethier and Markusen (1996). Ethier and Markusen (1996), in their two period product-cycle model, have examined the choice between exporting, licensing and subsidiary as the modes of serving the market of a developing country by an MNC. A wide range of equilibrium outcomes are obtained in their paper including exporting in both periods, exporting in first period followed by licensing in the second period, subsidiary in both periods etc. The equilibrium displays interplay of locational and internalisation considerations depending on the importance of knowledge capital, the discount rate, cost of exports etc. To keep the analysis simple we ignore the exporting option, but as opposed to their model where a subsidiary can be set up in any period, in our model we start with the policy of protection in the first period and consider the uncertainty in government policy in the sense that the economy may be liberalised in any future period with some positive probability. In our model the problem is such that the MNC would set up a subsidiary in the first period if it is allowed to do so and the problem analysed by Ethier and Markusen (1996) is not relevant here. Additionally, we introduce (a) the differences in the quality of transacted technologies and (b) imitation as a choice variable of the host firm, in our analysis. Very recently, Kabiraj and Yang (2001) have discussed the issue of innovation incentive of a local firm when an advanced technology is available through licensing from a foreign firm before the realisation of the government policy of either protection or free trade. They analyse how the uncertainty in government policy affects innovation and licensing decisions of a local firm. However, our focus is on the quality of the technology transfer by the multinational firm in a dynamic context when there is a possibility of imitation by the local firm.

The rest of the paper is organised as follows. In section 2, we present the basic framework of our model. The outcome associated with uncertainty in government policy is characterised in section 3. Section 4 presents the results with respect to the basic parameters of our model. Section 5 concludes the discussion. Some proofs are relegated to the appendix.

2. THE MODEL

Let us assume that the superior technology yields a profit in the domestic market amounting to Π and the inferior one yields an amount 'a' in every period under monopoly (obviously $\Pi > a$). There is a large 'technological gap' between the superior and inferior technologies such that if a firm uses superior technology for production it would be able to monopolise the market and the other firms with the inferior technology would go out of business.[5] For simplicity we assume that even the inferior technology of the MNC is better than the host firm's existing technology and the host firm cannot innovate these technologies independently. There is no fixed cost for setting up a subsidiary in the host country and the profits are net of variable costs.[6] Both the firms are risk neutral. Let δ be the common discount factor ($0 < \delta < 1$). We assume that the MNC can not export to the host country because of prohibitive tariff restrictions. For simplicity, we take the imitation cost to be zero for inferior technology and 'k' for superior technology. So, imitation is a choice variable only for the superior technology. By technology transfer we mean the transfer of know-how along with some complementary inputs. When the host firm imitates, it learns the know-how and also develops the capabilities to provide the associated complementary inputs. When the business is fully controlled by the MNC there is no possibility of dissemination of technological know-how. If the two firms compete with the same superior technology then each firm gets a Cournot duopoly profit Z in every period.

We assume that the two parties cannot write any enforceable long term contract on technology transfer and on the entry of the MNC in the future. We also assume that the parties cannot write contract forbidding imitation of the technologies. This can be justified on the ground that due to the deliberate omission of the government and the local court with nationalist feelings, the MNC cannot enforce any contract forbidding imitation, in the local court.[7]

We consider an infinite period game. We assume that the first period starts with the policy of protection. As a result, the MNC cannot set up a subsidiary on its own in the first period. We allow the possibility of uncertainty in government policy in the sense that the economy will be liberalised in the next period with some positive probability. Both the MNC and the host firm have a common belief about the possibility of liberalisation in the next period and this belief remains unchanged as long as the economy is

[5] Our analysis will go through even with a smaller 'technological gap' between the superior and inferior technologies than assumed here. In case of smaller technological gap, there will be possibility of competition between the host firm holding the inferior technology and the MNC's subsidiary with the superior technology in some subgames. We assume that this competition takes place *a la* Cournot and qualitatively similar analysis will follow. However, given the structure of the problem the technological gap should not be very close. For simplicity, we make the assumption of large technological gap.

[6] If we assume that there is a cost of setting up a wholly owned subsidiary, the MNC's payoff from the subsidiary would be net of that cost.

[7] This hypothesis is related to the empirical findings on patent protection in developing countries. In IFC survey of 16 countries (Mansfield (1994)), it was reported that the countries perceived to have the weakest patent protections are India, Thailand, Brazil and Nigeria.

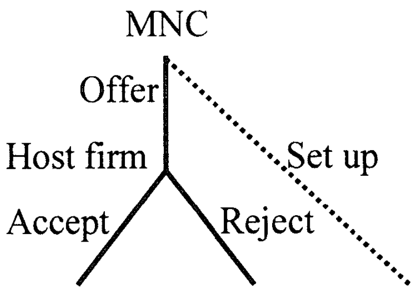


Figure 1.

not liberalised.[8] Once the state of the economy is liberalised, it would remain so forever.

The MNC's problem is to decide on which technology to transfer and when. We now describe the structure of the game. At the beginning of each period the parties observe the government policy of either protection or liberalisation. After observing the chosen policy, they play the following stage-game in each period. If the chosen policy is protection, the MNC makes an offer and the host firm either accepts or rejects the offer. If the chosen policy is liberalisation, the MNC has an additional option of setting up a wholly owned subsidiary. Thus, the stage-game can be represented by Figure 1 above.

The offer specifies the type of technology to be transferred and the payment to be made to the MNC. The option of not making an offer can be thought of as making an unacceptable offer, which gets rejected. At the end of each period the profits are realised. We assume that whenever the host firm receives a weakly greater payoff from acceptance than rejection, it would accept the offer. If the host firm accepts the offer, it may choose to imitate the technology. The benefit of imitation is that the host firm can independently operate with the same technology from the next period onwards.

At any period how the above stage-game will be played would depend on the history of that period. The history in any period refers to the path about how the game has already been played in the past periods. Thus, the history provides the initial condition of a subgame. Note that in any period if the government policy is protection, the MNC has to decide only on which technology to transfer. This decision depends on the existing technological capability of the host firm in that period. So, the history depends on whether the host firm has learnt the superior technology (ST) or inferior technology (IT) in the past. Since the imitation cost for inferior technology is zero, the inferior technology is learnt once it is transferred. Note that once the superior technology has been learnt, it does not matter for the subsequent subgames whether the inferior technology had been learnt (given) or not, in the past. Thus, the relevant histories can be represented by Figure 2.

In words, we have three relevant histories for the subgames under protection:

S1: The superior technology has already been learnt (L).

[8] Even if we allow the belief to alter depending on the outcome of the previous periods, our characterisation of the equilibrium goes through with revised belief and given history of technology transfer.

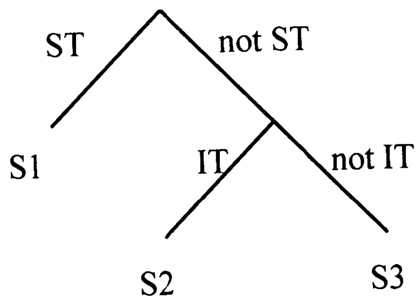


Figure 2.

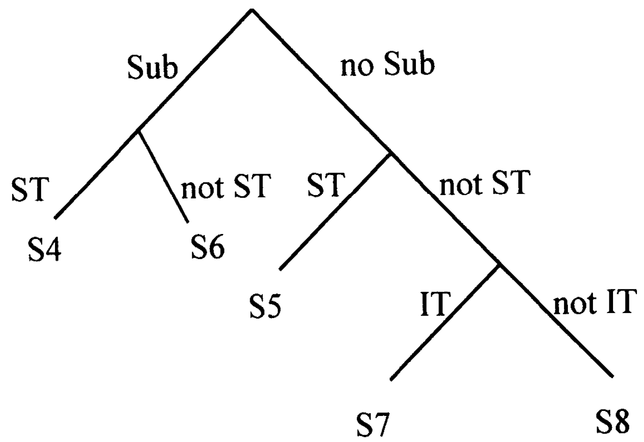


Figure 3.

S2: The superior technology has not been learnt (NL) but the inferior technology has been transferred.

S3: The superior technology has not been learnt and the inferior technology has not been transferred.

Similarly, in any period under liberalisation, the history depends on both the technological capability of the host firm, as well as on whether the subsidiary (Sub) of the MNC is in place or not. Thus, the relevant histories can be represented by Figure 3.

However, it is immaterial for the following subgame whether the inferior technology has been transferred in the past or not, once the superior technology is learnt (given by S4, S5). Also note that once the subsidiary has been set up and the host firm has not learnt the superior technology, it is not relevant whether or not the host firm knows the inferior technology, as the market would be served under monopoly by the subsidiary unit (in S6). Thus, we have five relevant histories (S4–S8) for the subgames under liberalisation.

S4: The superior technology has been learnt by the host firm and the subsidiary has also been set up.

S5: The superior technology has been learnt by the host firm but the subsidiary is not yet set up.

S6: The superior technology has not been learnt by the host firm but the subsidiary is already set up.

S7: The host firm has the inferior technology but has not learnt the superior one and the MNC has not set up a subsidiary yet.

S8: The host firm has not learnt any of the technologies and the MNC is yet to set up a subsidiary.[9]

Note that any particular period of the game would have any one of the eight histories (S1–S8). Ours is an infinite period game. However, we concentrate on the equilibrium that is achieved as a limiting equilibrium of the finite period version of the game, by extending the horizon to infinity. Incidentally, this equilibrium turns out to be unique in our model. The reason for doing this is that the problem of technology transfer is essentially a finite period problem because some new technology would come in and the present technology would be obsolete after a finite period. Instead of taking some arbitrary finite periods, we analyse the infinite period game.[10]

Additionally, we assume the following:

(A1). $\delta\Pi/(1-\delta) - k > 0$.

(A2). The reservation payoff of the host firm is zero without the MNC's technology.

(A3). We denote the equilibrium payoffs of the MNC and the host firm by $Y(\cdot)$ and $V(\cdot)$ respectively corresponding to different histories.

Without assumption (A1), the imitation of the superior technology is not worthwhile even if the market is served under monopoly by the host firm for all periods. Although the host firm's reservation payoff is assumed to be zero by (A2), but once the host firm learns the MNC's technology its payoff in the subsequent subgames improves depending on the government policy realisation.[11]

To analyse the outcome associated with uncertain government policy, first we need to characterise the outcomes in all possible subgames associated with the case of liberalisation.

Consider the case when the government announces the policy of liberalisation in some period. Since we have assumed that government policy is irreversible in nature, liberalisation would prevail from that period onwards. We have already listed the relevant histories that may be observable in any period under liberalisation. Suppose the game lasts till the T-th period, starting from any period t. Now this finite period version

[9] Note the difference between the histories S7 and S8. In S7, the host firm has been transferred the inferior technology in some earlier period. In S8 the host firm does not have the inferior technology. Thus, the history S8 can correspond to the first period of the game under liberalisation. However, the history S7 can only arise provided the game has started at least one period earlier. Also note equations (17) and (18) to see how they are relevant in different subgames. The outcomes in the subgames with either history are the same in the given game we are considering. The outcomes would be different in the case of a smaller technological gap where the host firm with inferior technology is able to compete with the MNC's subsidiary with superior technology.

[10] We need at least three periods to demonstrate the importance of inferior technology in affecting the incentive for imitation of the superior technology.

[11] As a result of technology transfer and learning by the host firm, the host firm's payoff in the subsequent subgame may improve, however these outcomes in the subgames are anticipated by the MNC and accordingly upfront license fee is charged.

of the game can be solved through backward induction. Thus, we write the equilibrium payoffs in the last period for different histories below.

$$\begin{aligned} Y_T(\text{S4}) &= Z & V_T(\text{S4}) &= Z \\ Y_T(\text{S5}) &= Z & V_T(\text{S5}) &= Z \\ Y_T(\text{S6}) &= \Pi & V_T(\text{S6}) &= 0 \\ Y_T(\text{S7}) &= \Pi & V_T(\text{S7}) &= 0 \\ Y_T(\text{S8}) &= \Pi & V_T(\text{S8}) &= 0 \end{aligned}$$

In S4, the MNC has no more moves left in the stage-game, since the host firm has learnt the superior technology and the subsidiary of the MNC is already in place. Thus, the market is served under duopoly competition leading to the profits Z for each firm. In S5, the host firm has already learnt the superior technology, so the MNC can at the best set up a subsidiary to get the duopoly profit Z. In S6, there is no point for the MNC to transfer the superior technology since it has a subsidiary in operation, which serves the market under monopoly. In S7 and S8, the MNC may either set up a subsidiary or offer the superior technology to the host firm to get Π and the host firm would not incur the cost of imitation since it is the last period. Suppose, by backward induction we have defined all the equilibrium payoffs and strategies till the period $t+1$ starting from the last period T. Let us calculate the same for period t. The MNC and the host firm's payoffs from all future periods including the current one are:

$$\begin{aligned} Y_t(\text{S4}) &= Z + \delta Y_{t+1}(\text{S4}) & V_t(\text{S4}) &= Z + \delta V_{t+1}(\text{S4}) \\ Y_t(\text{S5}) &= Z + \delta Y_{t+1}(\text{S4}) & V_t(\text{S5}) &= Z + \delta V_{t+1}(\text{S4}) \\ Y_t(\text{S6}) &= \Pi + \delta Y_{t+1}(\text{S6}) & V_t(\text{S6}) &= 0 \\ Y_t(\text{S7}) &= \Pi + \delta Y_{t+1}(\text{S7}) & V_t(\text{S7}) &= 0 \\ Y_t(\text{S8}) &= \Pi + \delta Y_{t+1}(\text{S8}) & V_t(\text{S8}) &= 0\,. \end{aligned}$$

The equilibrium outcomes in histories S4 and S6 are similar to those discussed above for the last period. Note that in history S5 the superior technology has been learnt by the host firm but the subsidiary is not yet set up by the MNC. Now in this situation since the policy is liberalisation, the MNC would set up a subsidiary to get the duopoly profit Z in the present period and then in the next period the subgame corresponds to history S4. In S7, the MNC is better off by setting up a subsidiary to get Π in every period. This is because: (1) if the host firm does not imitate, then to make an acceptable offer, the MNC has to allow the host firm to get 'a' in every period. (2) If the host firm does imitate, there will be loss on two counts: (a) imitation cost, and (b) loss due to duopoly competition after imitation, as the game reaches S5 in the next period. In S8, the MNC can either set up a subsidiary or transfer the superior technology. In case the host firm does not learn (imitate) then the MNC is indifferent between the two options. However, if the host firm learns (imitates) the superior technology then to avoid the loss suffered by the MNC due to imitation and subsequent future competition, the MNC would prefer to set up a subsidiary. Thus, setting up a subsidiary is a weakly dominant strategy.

Note that this finite horizon game has a unique equilibrium as described above. When the horizon approaches infinity, the payoffs converge to their respective numbers given below. To see that the payoffs are actually converging, let us consider the case of history S4 as an example. In history S4, the payoff of the MNC, when the game lasts till period T starting from a period t, is given below.

$$Y_t(\text{S4}) = Z + \delta Z + \delta^2 Z + \cdots + \delta^{T-t} Y_T(\text{S4}) < \Pi + \delta \Pi + \delta^2 \Pi + \cdots + \delta^{T-t} \Pi$$

(since $Z < \Pi$)

$$\text{Or, } Y_t(\text{S4}) = \frac{(1-\delta^{T-t})}{1-\delta} Z + \delta^{T-t} Y_T(\text{S4}) < \frac{(1-\delta^{T-t+1})}{1-\delta} \Pi .$$

When T tends to infinity, with $\delta < 1$, the RHS tends to $\Pi/(1-\delta)$. So the LHS, being a monotonic increasing sequence bounded above, converges to $Y(\text{S4}) = Z/(1-\delta)$ when T tends to infinity. In particular, defining $Y(\cdot)$ and $V(\cdot)$ as the limiting payoffs corresponding to different history when the horizon of the game approaches infinity, we have

$$Y(\text{S4}) = Z/(1-\delta) \qquad V(\text{S4}) = Z/(1-\delta) \tag{1}$$

$$Y(\text{S5}) = Z/(1-\delta) \qquad V(\text{S5}) = Z/(1-\delta)^{12} \tag{2}$$

$$Y(\text{S6}) = \Pi/(1-\delta) \qquad V(\text{S6}) = 0 \tag{3}$$

$$Y(\text{S7}) = \Pi/(1-\delta) \qquad V(\text{S7}) = 0 \tag{4}$$

$$Y(\text{S8}) = \Pi/(1-\delta) \qquad V(\text{S8}) = 0 \tag{5}$$

Suppose the government in the host country begins with liberalisation in the first period. This situation corresponds to the history S8 here. Given the structure of the problem, the MNC would set up a subsidiary in the very first period in order to serve the market in every period under monopoly. Thus, it gets the total discounted payoff $\Pi/(1-\delta)$. Note the difference between our model and that of Ethier and Markusen (1996) mentioned in the introduction.

3. UNCERTAIN GOVERNMENT POLICY

We now start with the situation where the government follows the policy of protection in the first period. As a result, the MNC cannot set up a subsidiary in the first period. However the government of the host country may liberalise the economy in any future period. We allow for the possibility of uncertainty in government policy in the sense that the economy will be liberalised in the next period with some positive probability. Suppose, both parties have a common belief that the economy will be liberalised in the

[12] Note that in the subgames with history S5 and S4, the firms can cooperate in the product market to divide the monopoly profit Π as (say) $\Pi/2$ ($> Z$) each, given the infinite period game where the cooperation will be sustainable depending on the value of δ. This would simply change the value of Z to $\Pi/2$ in the calculations of outcomes in the subgames. The same qualitative results will hold. However, we stick to our assumption of Cournot competition in the present analysis.

next period with a fixed probability p. Once the state of the economy is liberalised, it would remain so forever. Thus, the uncertainty about government policy persists as long as the government continues with the policy of protection. As in the earlier section, we first describe the outcome for finite period game and then we derive the limiting equilibrium by extending the horizon of the game to infinity.

First consider the history S1. In the last period T, the host firm serves the market with the imitated technology under monopoly as the MNC is not allowed to enter with a subsidiary. So the payoffs are $Y_T = 0$ and $V_T = \Pi$. Now, suppose by backward induction, we have defined the equilibrium for all periods uptill $t+1$ starting from T. The equilibrium payoffs in period t, depending on the future government policy can be written as:

$$Y_t(\mathrm{S1}) = 0 + p\delta Y_{t+1}(\mathrm{S5}) + (1-p)\delta Y_{t+1}(\mathrm{S1}),$$
$$V_t(\mathrm{S1}) = \Pi + p\delta V_{t+1}(\mathrm{S5}) + (1-p)\delta V_{t+1}(\mathrm{S1}).$$

In this history, the host firm serves the market with superior technology under monopoly as long as there is protection and the MNC sets up a subsidiary when there is liberalisation. This describes the subgame perfect equilibrium outcome in this history. The equilibrium is uniquely defined. When the horizon goes to infinity, the payoffs are also uniquely defined [by using (2)] as:

$$Y(\mathrm{S1}) = \frac{p\delta Z/(1-\delta)}{[1-\delta(1-p)]}, \tag{6}$$

and

$$V(\mathrm{S1}) = \frac{\Pi + p\delta Z/(1-\delta)}{[1-\delta(1-p)]}. \tag{7}$$

Now consider the history S2. In this history S2, the MNC has two options: (i) supply the superior technology on acceptable terms or (ii) make an unacceptable offer and wait till the next period to take an optimal decision. First we determine the outcome in the last period T. Note that the host firm can receive profit 'a' by rejecting the offer of superior technology as it has the inferior technology. So in the last period, the MNC would transfer the superior technology to get $(\Pi - a)$ and the host firm accepts this offer and does not imitate the superior technology. Again by backward induction, we analyse the outcome in period t.

The host firm's reservation payoff in this history S2, i.e., the amount it can get by rejecting all the offers of the MNC, is given by

$$V_t(\mathrm{S2}) = a + \delta p V_{t+1}(\mathrm{S7}) + \delta(1-p)V_{t+1}(\mathrm{S2}). \tag{8}$$

When T tends to infinity, by using (4) we find

$$V_t(\mathrm{S2}) \to V(\mathrm{S2}) = \frac{a}{[1-\delta(1-p)]}. \tag{9}$$

Now the learning incentive for the superior technology when the host firm has the inferior technology, (LII), is given by the net payoff the host firm gets by learning:

$$\mathrm{LII} = -k + \delta p[V_{t+1}(\mathrm{S5}) - V_{t+1}(\mathrm{S7})] + \delta(1-p)[V_{t+1}(\mathrm{S1}) - V_{t+1}(\mathrm{S2})]$$

When $T \rightarrow \propto$, after putting the values of $V(\cdot)$ from (2), (4), (7) and (9) we get,

$$\text{LII} = -k + \frac{\delta(1-p)(\Pi - a) + p\delta Z/(1-\delta)}{[1-\delta(1-p)]} \tag{10}$$

When LII > 0, the host firm learns the superior technology. By supplying the superior technology the maximum upfront payment the MNC can charge is $\Pi - a + \text{LII}$. This is for the following reason. Suppose the MNC charges slightly more, i.e., $\Pi - a + \text{LII} + \varepsilon$ ($\varepsilon > 0$ but small). Then the offer gets rejected. This is because after accepting the offer it is not worthwhile for the host firm to imitate, since it does not cover its reservation payoff $V(\text{S2})$. However, if the host firm does not imitate the superior technology then it would pay only $(\Pi - a)$ in the current period, since the MNC cannot commit to supply the complementary inputs associated with the superior technology in the future. Similarly, if the MNC charges less than $(\Pi - a + \text{LII})$, it always pays the host firm to imitate once it gets the opportunity to use the superior technology.

When LII > 0, by making an acceptable offer of the superior technology, the maximum payoff that the MNC can expect to get is $Y_t^L(\text{S2}) = \Pi - a + \text{LII} + \delta p Y_{t+1}(\text{S5}) + \delta(1-p)Y_{t+1}(S1)$. When LII ≤ 0, the host firm does not learn the superior technology (NL) and so by transferring the superior technology the MNC gets $Y_t^{NL}(\text{S2}) = \Pi - a + \delta p Y_{t+1}(\text{S7}) + \delta(1-p)Y_{t+1}(\text{S2})$. By making an unacceptable offer the MNC can get by waiting for one period,

$$Y_t^w(\text{S2}) = 0 + \delta p Y_{t+1}(\text{S7}) + \delta(1-p)Y_{t+1}(\text{S2}).$$

Clearly, when LII ≤ 0 then $Y_t^{NL}(\text{S2}) > Y_t^w(\text{S2})$. As T tends to infinity [by using (4)] $Y_t^{NL}(\text{S2})$ tends to

$$Y^{NL}(\text{S2}) = \frac{\Pi - a + p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}. \tag{11}$$

When LII > 0, to find the optimal strategy we compare the payoffs $Y_t^L(\text{S2})$ and $Y_t^w(\text{S2})$ and state the following lemma.

LEMMA 1. *Suppose* LII > 0, *then* $Y_t^L(\text{S2}) \geq Y_t^w(\text{S2})$ *for large enough T iff,*

$$\frac{(\Pi - a) + \delta p 2Z/(1-\delta)}{[1-\delta(1-p)]} - k \geq \frac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}.$$

[The proof of this lemma and also the subsequent proofs are relegated to the appendix].

In S2, when LII > 0, the MNC may either transfer the superior technology or wait, depending on their respective payoffs. Thus, for our purpose, we write the payoffs for infinite period game as

$$Y^L(\text{S2}) = \frac{\Pi - a + \delta p 2Z/(1-\delta)}{[1-\delta(1-p)]} - k, \tag{12}$$

and

$$Y^w(\text{S2}) = \frac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}. \tag{13}$$

In history S3, the MNC has three options: (i) transfer the superior technology at an acceptable term, (ii) transfer the inferior technology at an acceptable term, and (iii) make an unacceptable offer and wait for the next period to take the optimal decision. Since the host firm has neither of the MNC's technologies, the host firm's reservation payoff is zero in this case (i.e., $V_t(\mathrm{S3}) = 0$ by assumption A2). Thus, when the MNC offers any technology, it would charge the upfront payment such that the host firm receives zero by accepting the offer. Note that the history S3 corresponds to the situation in the first period of our full game, all other histories corresponds to different subgames, which are possible only in later periods of the game. In the last period the MNC would transfer the superior technology by charging a payment Π and the host firm would accept that. Now by backward induction we analyse the outcome for some period t.

First consider the option of offering the superior technology. Here the learning incentive (LI) of the host firm is the net payoff it gets by learning, which is given as:

$$\mathrm{LI} = -k + \delta p[V_{t+1}(\mathrm{S5}) - V_{t+1}(\mathrm{S8})] + \delta(1-p)[V_{t+1}(\mathrm{S1}) - V_{t+1}(\mathrm{S3})].$$

When $T \to \infty$, after putting the values of $V(\cdot)$ from (2), (5), (7) and assumption A2, we find

$$\mathrm{LI} = -k + \frac{\delta(1-p)\Pi + p\delta Z/(1-\delta)}{[1-\delta(1-p)]} \tag{14}$$

When $\mathrm{LI} > 0$, the host firm would learn the superior technology if it is transferred. By making an offer of superior technology at an upfront fee $\Pi + \mathrm{LI}$, which will be accepted by the host firm, the MNC gets the payoff $Y_t^L(\mathrm{S3}) = \Pi + \mathrm{LI} + \delta p Y_{t+1}(\mathrm{S5}) + \delta(1-p)Y_{t+1}(\mathrm{S1})$.

When $T \to \infty$, using (2) and (6) we get,

$$Y^L(\mathrm{S3}) = \frac{\Pi + p\delta 2Z/(1-\delta)}{[1-\delta(1-p)]} - k \tag{15}$$

When $\mathrm{LI} \leq 0$, the host firm does not imitate the superior technology if it is transferred. So the MNC can charge each period's profit by transferring the superior technology in each period and the host firm would accept that offer in each period. However, when the economy is liberalised the MNC may set up the subsidiary to get the same payoff. Thus, in no learning (NL) situation the MNC gets

$$Y_t^{NL}(\mathrm{S3}) = \Pi + \delta p Y_{t+1}(\mathrm{S8}) + \delta(1-p)Y_{t+1}(\mathrm{S3}).$$

When $T \to \infty$, by using (5) we get,

$$Y^{NL}(\mathrm{S3}) = \Pi/(1-\delta). \tag{16}$$

Consider the second option of offering the inferior technology. If the host firm accepts the offer of inferior technology, its total payoff is the same as in S2, $V_t(\mathrm{S2}) = a + \delta p V_{t+1}(\mathrm{S7}) + \delta(1-p)V_{t+1}(\mathrm{S2})$ [from (8)]. The host firm accepts the offer if the upfront payment does not exceed $V_t(\mathrm{S2})$. Hence, by supplying the inferior technology, the MNC obtains

$$Y_t^I(\mathrm{S3}) = V_t(\mathrm{S2}) + \delta p Y_{t+1}(\mathrm{S7}) + \delta(1-p)Y_{t+1}(\mathrm{S2}). \tag{17}$$

By the third option that is by waiting option, the MNC expects to get

$$Y_t^w(\mathrm{S3}) = 0 + \delta p Y_{t+1}(\mathrm{S8}) + \delta(1-p)Y_{t+1}(\mathrm{S3}). \tag{18}$$

Now by comparing the option of transferring the inferior technology and waiting we write,

LEMMA 2. *For any $t < T$, i.e., if the game lasts for more than one period then* $Y_t^I(\mathrm{S3}) > Y_t^w(\mathrm{S3})$.

Thus by Lemma 2, the optimal strategy in this history S3 is to transfer either superior or inferior technology depending on the associated payoffs.

Consider the expressions of LII and LI (given by (10) and (14) respectively). Note that the incentive for learning the superior technology is less when the host firm has the inferior technology as compared to the situation when it does not have that (i.e., LII $<$ LI). In the absence of long term contract the supply of inferior technology acts as a pre-commitment of a payoff to the host firm. This is because with inferior technology the host firm is assured of a profit 'a' as long as the government chooses to continue the policy of protection. As a result, the premium it gets by imitation of superior technology is less as compared to the situation where the host firm does not have the inferior technology. In our model the imitation incentive of superior technology is being affected through a channel which is very different from Gallini (1984).[13]

As LII $<$ LI the following three scenarios are possible depending on the parameter values: (a) LI ≤ 0 and LII < 0, (b) LI > 0 and LII ≤ 0, and (c) LI > 0 and LII > 0. The following three lemmas would characterise the outcome of our infinite period game in history S3.

LEMMA 3. *If* LI ≤ 0, *the optimal strategy of the MNC is to transfer the superior technology and thereby, it gets* $Y(\mathrm{S3}) = Y^{NL}(\mathrm{S3}) = \Pi/(1-\delta)$.

When the host firm does not imitate the superior technology then the MNC can ask for Π by supplying it in every period as long as there is protection and the host firm accepts that offer. When the economy is liberalised, the MNC may set up a subsidiary. However the payoffs are same for the MNC with both licensing and subsidiary options. In any case the market is always served under monopoly.

LEMMA 4. *When* LI > 0 *and* LII ≤ 0, *the optimal strategy of the MNC is to transfer the inferior technology in the current period as* $Y^I(\mathrm{S3}) > Y^L(\mathrm{S3})$ *for large* δ. *The total payoff of the MNC, from the supply of inferior technology in the present period and subsequently following the optimal strategy, is* $Y(\mathrm{S3}) = Y^I(\mathrm{S3}) = Y^I(Y^{NL}(\mathrm{S2})) = a + \delta\Pi/(1-\delta)$.

The transfer of the inferior technology involves an initial loss to the MNC as it could not reap the surplus generated by the superior technology in the first period. However, the MNC takes the chance of liberalisation to take place in the next period and also gets the advantage of no imitation of the superior technology when it is transferred under protection in the next period. Thus, when δ is large (and of course greater than half), the

[13] Gallini (1984) shows that an incumbent firm may license its production technology to reduce the incentive of a potential entrant to develop a better technology on its own.

MNC does better by transferring the inferior technology in the first period. We assume δ to be large for the rest of our analysis. It should be noted also that $\delta < 1$ by assumption.

LEMMA 5. *When* LI > 0 *and* LII > 0, *the MNC transfers the superior or inferior technology depending on their respective payoffs. Thus, the MNC obtains*

$$Y(\text{S3}) = Y^L(\text{S3}), \text{ if } Y^L(\text{S2}) \geq Y^w(\text{S2});$$
$$= Y^I(\text{S3}), \text{ if } Y^L(\text{S2}) < Y^w(\text{S2}).$$

Here

$$Y^I(\text{S3}) = Y^I(Y^w(\text{S2})) = \frac{a}{[1-\delta(1-p)]} + \frac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}. \tag{19}$$

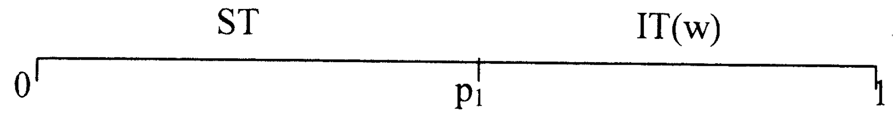
When both the learning conditions are satisfied, the inferior technology is given only when the MNC wants to wait for liberalisation in order to set up a subsidiary. When the transfer of superior technology is optimal in the next period under protection (i.e., in S2), even though the host firm imitates it, then it is also optimal in the current period in S3. In this case when the superior technology is transferred, the market becomes a duopoly whenever the economy is liberalised.

The above analysis is carried out with the assumption that the parties cannot write long term contract on technology transfer and on entry of the MNC. Let us note what difference it would make if we allow the MNC and the host firm to write long term contract on technology transfer and on entry of the MNC in the future. First suppose that they can commit on the technology transfer only. Then the MNC can commit to supply the superior technology forever. Note that the MNC can enter under liberalisation in future. Under this circumstance the MNC would charge $\dfrac{\Pi + p\delta Z/(1-\delta)}{[1-\delta(1-p)]}$ from the host firm and the host firm would accept that offer. The host firm would not imitate the superior technology as it is assured of getting that forever under the given contract. Since the MNC would also enter with a subsidiary whenever the economy is liberalised, its total payoff would be $\dfrac{\Pi + p\delta 2Z/(1-\delta)}{[1-\delta(1-p)]}$. On the other hand, if two parties can also write contract forbidding entry of the MNC in any future period, then the MNC can commit to supply the superior technology forever and would never enter in future. In that case the MNC can get the total payoff $\Pi/(1-\delta)$ by supplying the superior technology and the market will always be served under monopoly by the host firm.

4. RESULTS ON EQUILIBRIUM CHARACTERISATION

In the previous section we have seen how the equilibrium in S3 depends upon whether it is worthwhile for the host firm to imitate the superior technology or not, i.e., on the sign of the expressions LI or LII. The signs of these expressions are in turn determined by the basic parameters of the model: Π, Z, a, p, k and δ. Therefore, the result of the last section can be stated in terms of the basic parameters. It is easy to check that under Cournot competition with linear demand and constant marginal cost functions, the

If $\Pi - a < k + \delta(\Pi - 2Z)/(1 - \delta)$



and if $\Pi - a \geq k + \delta(\Pi - 2Z)/(1 - \delta)$

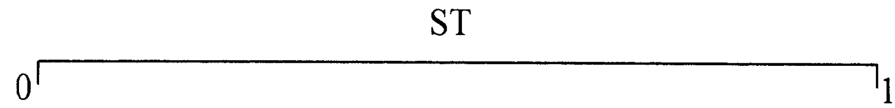


Figure 4.

assumption of large 'technological gap' between the superior and the inferior technologies implies that $\Pi - a > Z$.[14] Thus, we have the following three cases to consider.

Case (a): First consider the parameter restriction $\delta Z/(1 - \delta) - k > 0$. Here both the learning conditions are satisfied irrespective of the values of p [from (10) and (14)]. From Lemma 1, we write $Y^L(\text{S2}) \geq Y^w(\text{S2})$ iff, $\dfrac{\Pi - a + \delta p 2Z/(1 - \delta)}{[1 - \delta(1 - p)]} - k \geq \dfrac{p\delta\Pi/(1 - \delta)}{[1 - \delta(1 - p)]}$. It is easy to see the following.

LEMMA 6. *If $\Pi - a < k + \delta(\Pi - 2Z)/(1 - \delta)$, there exists a critical probability p_1, such that for $p \leq p_1$, $Y^L(\text{S2}) \geq Y^w(\text{S2})$ and for $p > p_1$, $Y^L(\text{S2}) < Y^w(\text{S2})$ where* $p_1 = \dfrac{\Pi - a - k(1 - \delta)}{\delta\left[\dfrac{\Pi - 2Z}{1 - \delta} + k\right]}$; *otherwise $Y^L(\text{S2}) > Y^w(\text{S2})$ for all values of p.*

So we write the MNC's optimal strategy of technology transfer in the first period with the help of Lemmas 5 and 6.

PROPOSITION 1. *Suppose $\delta Z/(1 - \delta) > k$. Now if $\Pi - a < k + \delta(\Pi - 2Z)/(1 - \delta)$ then for $p \leq p_1$, the MNC would transfer the superior technology; for $p > p_1$, it would transfer the inferior technology. And if $\Pi - a \geq k + \delta(\Pi - 2Z)/(1 - \delta)$ then, $Y^L(\text{S3}) \geq Y^I(\text{S3})$, and therefore it would transfer the superior technology.*

Alternatively, in this case the relationship between the quality of technology transfer by the MNC and the probability of liberalisation can be plotted in Figure 4.

Here the inferior technology (IT(w)) is transferred by the MNC when it wants to wait till the economy is liberalised in order to set up a subsidiary. Otherwise, the superior technology is transferred.

[14] Consider the inverse demand function $P = A - bQ$ and suppose the cost function of the superior technology is $C = cQ$ (where A, b, $c > 0$ and $A > c$). Now $\Pi = \dfrac{(A - c)^2}{4b}$ and $Z = \dfrac{(A - c)^2}{9b}$. The assumption of large 'technological gap' between the superior and inferior technologies implies that the marginal cost of the inferior technology should not be lower than the monopoly price charged under the superior technology i.e., $(A + c)/2$. As a result, $a \leq \dfrac{(A - c)^2}{16b}$.

Case (b): Consider the parameter restrictions: $\delta Z/(1-\delta) \leq k < \delta(\Pi - a)/(1-\delta)$. From the learning conditions (10) and (14), the following behaviour would emerge in this situation. There exists a critical probability p_2 such that for $p \geq p_2$, LI ≤ 0; and for $p < p_2$, LI > 0. Also there exists a critical probability p_3 such that for $p \geq p_3$, LII ≤ 0; and for $p < p_3$, LII > 0. Now it is easy to check that $p_2 > p_3$ from their respective expressions.[15] Intuitively, note that p_2 and p_3 are cut-off probabilities at which LI and LII are equal to zero respectively. Since the incentive for learning the superior technology is higher without inferior technology (LI) than with it (LII) and both functions are negatively related to p, we have $p_2 > p_3$. Thus, we have the following learning behaviour with respect to p.

For $p \geq p_2 > p_3$, LI ≤ 0 and LII < 0;
for $p_2 > p \geq p_3$, LI > 0 and LII ≤ 0;
and for $p_2 > p_3 > p$, LI > 0 and LII > 0.

Note that the existence of p_1 is relevant only when LI and LII are greater than 0 (from Lemmas 1 and 6). Now we have $p_1 < p_3$ if $(\Pi - a)(\Pi - a - Z) < (\Pi - Z)\left(\frac{\delta(\Pi - a)}{1-\delta} - k\right)$ holds (from their respective expressions).

With the help of Lemmas 3, 4, 5 and 6 we get the next proposition.

PROPOSITION 2. *Suppose $\delta Z/(1-\delta) \leq k < \delta(\Pi - a)/(1-\delta)$. The MNC's optimal strategy and the associated payoffs are as follows.*

(i) *For $p \geq p_2 > p_3$, transfer the superior technology to get $Y(\text{S3}) = Y^{NL}(\text{S3}) = \Pi/(1-\delta)$;*

(ii) *for $p_2 > p \geq p_3$, transfer the inferior technology to get $Y(\text{S3}) = Y^{I}(\text{S3}) = a + \delta\Pi/(1-\delta)$;*

and

(iii) (a) *if $\Pi - a < k + \delta(\Pi - 2Z)/(1-\delta)$ and $(\Pi - a)(\Pi - a - Z) < (\Pi - Z)\left(\frac{\delta(\Pi - a)}{1-\delta} - k\right)$ hold then for $p_2 > p_3 > p > p_1$, transfer the inferior technology to get $Y(\text{S3}) = Y^{I}(Y^{w}(\text{S2}))$ and for $p_2 > p_3 > p_1 \geq p$ transfer the superior technology to get $Y(\text{S3}) = Y^{L}(\text{S3}) = \frac{\Pi + p\delta 2Z/(1-\delta)}{[1-\delta(1-p)]} - k$;*

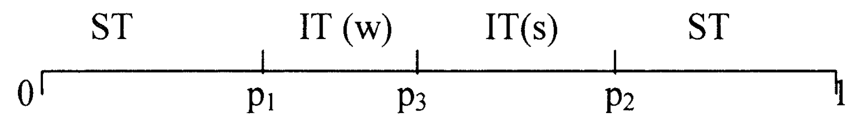
And (b) *if $\Pi - a < k + \delta(\Pi - 2Z)/(1-\delta)$ and $(\Pi - a)(\Pi - a - Z) < (\Pi - Z)\left(\frac{\delta(\Pi - a)}{1-\delta} - k\right)$ do not hold then for $p_2 > p_3 > p$, transfer the superior technology to get $Y(\text{S3}) = Y^{L}(\text{S3})$.*

Alternatively, in this case the relationship between the quality of technology transfer by the MNC and the probability of liberalisation can be plotted in Figure 5.

Here we get a non-monotonic result on the quality of the technology transfer with respect to p. For higher p, the MNC supplies the superior technology because the host

[15] $p_2 = \dfrac{\delta\Pi - k(1-\delta)}{\delta\left(\Pi - \frac{Z}{1-\delta} + k\right)}$ and $p_3 = \dfrac{\delta(\Pi - a) - k(1-\delta)}{\delta\left[(\Pi - a) - \frac{Z}{1-\delta} + k\right]}$.

If $\Pi - a < k + \delta(\Pi - 2Z)/(1-\delta)$ and $(\Pi - a)(\Pi - a - Z) < (\Pi - Z)\left(\frac{\delta(\Pi - a)}{1-\delta} - k\right)$ hold,



Otherwise,

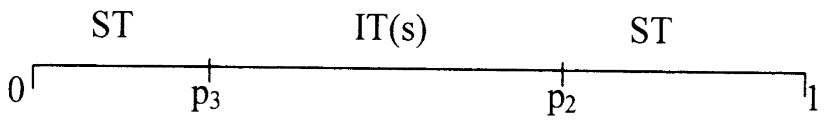


Figure 5.

firm does not imitate it (by Lemma 3). If p_1 does not exist, then also below p_3, the optimal strategy is to transfer the superior technology. On the other hand, if p_1 exists (see Lemma 6) then for (p_3, p_1), the optimal strategy is to transfer the inferior technology in order to wait (IT(w)) for the liberalisation to set up a subsidiary (by Lemmas 5 and 6). In $(p_2, p_3]$ range of probabilities the MNC will supply the inferior technology in the first period. In the second period if there is protection, the MNC will supply the superior technology, as there would not be any imitation then (by Lemma 4); otherwise, in liberalisation the MNC would set up a subsidiary (IT(s)). The consequent market structures with respect to p can be obtained from the discussions after the Lemmas 3, 4 and 5. Proposition 2 establishes that there is no direct relationship between the belief about the government's future liberalisation policy and the quality of technology transferred to the host country.

Let us discuss the above non-monotonic result in somewhat intuitive terms. Generally, for lower prior belief about the liberalisation the MNC would transfer the superior technology even though it is imitated as the probability of its entry with a subsidiary is low. For higher values of prior belief about liberalisation the MNC also transfers the superior technology. This is due to the fact that the probability of entry of the MNC with a subisidiary is higher, as a result the host firm's incentive for imitation is reduced so much that given the fixed cost of imitation, the host firm decides not to imitate the superior technology. Thus, the MNC transfers superior technology for higher prior belief also. However, for intermediate range of prior belief, inferior technology is supplied either because the MNC wants to wait for liberalisation to set up a subsidiary or because the transfer of inferior technology leads to no imitation of superior technology when the superior technology is transferred in the next period in case of protection.

Case (c): Now consider the last possibility $\delta(\Pi - a)/(1-\delta) \le k$. Since $\Pi - a > Z$, so $\delta Z/(1-\delta) - k < 0$. Here LII ≤ 0 for all values of p, but the value of LI is dependent on p_2 (already defined in case (b)). Thus, we write the optimal strategy of the MNC with the help of Lemmas 3 and 4.

PROPOSITION 3. *When $\delta(\Pi - a)/(1-\delta) \le k$, the MNC's optimal strategy and the payoffs are given as follows. For $p \ge p_2$, transfer the superior technology and get*

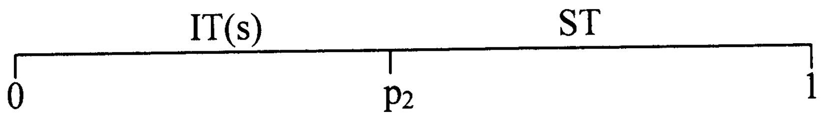


Figure 6.

$Y(S3) = Y^{NL}(S3) = \Pi/(1-\delta)$; and for $p < p_2$, transfer the inferior technology to get $Y(S3) = Y^{I}(S3) = a + \delta\Pi/(1-\delta)$.

Alternatively, in this case the quality of technology transfer by the MNC can be plotted in Figure 6.

Here the transfer of inferior technology affects the learning condition such that for all values of p the host firm does not imitate the superior technology when it has the inferior technology. So when the host firm does not imitate the superior technology, even without having the inferior technology (for $p \geq p_2$), the MNC's optimal strategy is to transfer the superior technology in the first period itself. However, when the host firm learns the superior technology if it is transferred in the first period, then the MNC transfers the inferior technology in the first period. From the second period onwards the MNC transfers the superior technology as long as there is protection and sets up a subsidiary whenever the economy is liberalised.

An interesting point to note is that the inferior technology is transferred in the first period even when the economy remains under protection forever (i.e., at $p = 0$). This is because the transfer of inferior technology in the first period helps the MNC to avoid the imitation cost of superior technology when the superior technology is transferred in the second period. Although the MNC gets less profit in the first period by an amount $(\Pi - a)$ but for large δ, this loss is outweighed by the saving on imitation cost, k, in this case.

5. CONCLUSION

This paper provides an analysis of international technology transfer by a multinational corporation in the context of a developing country. We have introduced the uncertainty in the government policy (of either protection or liberalisation) and its impact on the quality of technology transfer by the MNC. We characterise the optimal strategy of the MNC depending on the parameters of our model. Under certain parameter configuration, we have found that the superior technology may be transferred for high and low probability of liberalisation and for intermediate values of the probability of liberalisation, the inferior technology is transferred. Thus, we find a non-monotonic relationship between the quality of the technology transferred and the belief about the future liberalisation. We have shown that the transfer of inferior technology serves two purposes: (i) it affects the imitation incentive of the superior technology if it is transferred later; and (ii) when the MNC wants to wait for liberalisation to take place in the future, in the meantime, it offers the inferior technology to get some payment. Imitation is treated as a choice variable and it is shown that imitation occurs in equilibrium. As a result we find that the host firm may compete with the erstwhile technology licensor when the licensor enters with a subsidiary after liberalisation in the domestic economy. Thus, this approach has provided an endogenous theory of evolution of market structure. We also provide a different reason for inferior technology transfer under complete information when the markets are segregated.

APPENDIX

PROOF OF LEMMA 1: We prove it in two steps.

Step 1. If $\dfrac{(\Pi - a) + \delta p 2Z/(1-\delta)}{[1-\delta(1-p)]} - k \geq \dfrac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}$ then $Y_t^L(\text{S2}) \geq Y_t^w(\text{S2})$ for large enough T. Now define $Y_t^{w^*}$ = the MNC's payoff associated with the waiting option till liberalisation is the realised policy. We have already defined Y_t^w to be the optimal payoff associated with waiting at t only and then following the subsequent optimal strategy from period t+1 onwards. Obviously, $Y_t^w \geq Y_t^{w^*}$. Now suppose they are not equal. Then for any given horizon T_i, $\exists a\tau$, which is the earliest period, such that, at $\tau(T_i)$, $Y_\tau^{w^*} < Y_\tau^*$ (the optimal payoff associated with either learning or no learning). When $T_i \rightarrow \propto$, then $\tau(T_i)$ could either tend to some finite integer or to infinity. Let us suppose that $\tau(T_i)$ tends to some finite integer. Then $Y_\tau^{w^*} < Y_\tau^*$ as T_i tends to infinity. However, $Y_\tau^* = Y_\tau^L = \dfrac{(\Pi - a) + \delta p 2Z/(1-\delta)}{[1-\delta(1-p)]} - k$. So $Y_\tau^L > Y_\tau^{w^*}$. Now consider the period $\tau - 1$. Then $Y_{\tau-1}^L > Y_{\tau-1}^{w^*}$. Therefore, it contradicts that τ is the earliest period. Hence, $\tau(T_i)$ cannot tend to any finite integer when T_i tends to infinity. In other words, $\tau(T_i)$ tends to infinity when T_i tends to infinity, in that case the difference between $Y_t^{w^*}$ and Y_t^w vanishes. Hence if $\dfrac{(\Pi - a) + \delta p 2Z/(1-\delta)}{[1-\delta(1-p)]} - k \geq \dfrac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}$ then $Y_t^L(\text{S2}) \geq Y_t^w(\text{S2})$ for large enough T.

Step 2. If $\dfrac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]} > \dfrac{(\Pi - a) + \delta p 2Z/(1-\delta)}{[1-\delta(1-p)]} - k$, then $Y_t^w(\text{S2}) > Y_t^L(\text{S2})$ for large enough T. Suppose not true. Then there exists a subsequence $T_1, T_2 \cdots \propto$ such that $Y_t^L(T_i) > Y_t^w(T_i)$. But when T tends to infinity, $Y_t^w(T_i) \geq \dfrac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}$. So $Y_t^L(T_i) > Y_t^w(T_i) \geq \dfrac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}$. But this violates our "if" part for large enough T because $Y_t^L(T_i)$ tends to $\dfrac{(\Pi - a) + \delta p 2Z/(1-\delta)}{[1-\delta(1-p)]} - k$, as T tends to infinity. Hence $Y_t^w(\text{S2}) > Y_t^L(\text{S2})$ is proved.

These two steps taken together prove Lemma 1.

PROOF OF LEMMA 2: Note that $Y_{t+1}(\text{S7}) = Y_{t+1}(\text{S8})$ and $V_t(\text{S7}) = V_{t+1}(\text{S7}) = 0$. Now we rewrite $Y_t^I(\text{S3})$ from (17) by using (8) as $Y_t^I(\text{S3}) = a + \delta p Y_{t+1}(\text{S7}) + \delta(1-p)[Y_{t+1}(\text{S2}) + V_{t+1}(\text{S2})]$. Now by comparing with (18), since $Y_{t+1}(\text{S2}) + V_{t+1}(\text{S2}) \geq Y_{t+1}(\text{S3})$, so $Y_t^I(\text{S3}) > Y_t^w(\text{S3})$.

PROOF OF LEMMA 3: It trivially follows from the fact that this is the maximum available surplus in the relationship.

PROOF OF LEMMA 4: When LII ≤ 0, $Y(\mathrm{S2}) = Y^{NL}(\mathrm{S2})$. Thus, when T tends to infinity by using (17), (11) and (9) we get, $Y^I(\mathrm{S3}) = a + \delta\Pi/(1-\delta)$. Recall $Y^L(\mathrm{S3}) = \dfrac{\Pi + \delta p2Z/(1-\delta)}{[1-\delta(1-p)]} - k$ [from (15)]. Since LII ≤ 0, so, $\dfrac{\delta(1-p)(\Pi - a) + \delta pZ/(1-\delta)}{[1-\delta(1-p)]} - k \leq 0$ [from(10)].

Therefore,

$$\frac{\Pi + \delta p2Z/(1-\delta)}{[1-\delta(1-p)]} - k \leq \frac{\Pi + \delta p2Z/(1-\delta)}{[1-\delta(1-p)]} - \frac{\delta(1-p)(\Pi - a) + \delta pZ/(1-\delta)}{[1-\delta(1-p)]}$$

$$\begin{aligned} \text{Now RHS} &= \Pi + \frac{\delta(1-p)a}{1-\delta(1-p)} + \frac{\delta pZ/(1-\delta)}{1-\delta(1-p)} \\ &< \Pi + \delta Z/(1-\delta) \quad [\text{since } Z > a \text{ (see footnote 14)}] \\ &< a + \delta\Pi/(1-\delta) \ \text{ holds for } \delta > \frac{\Pi - a}{2\Pi - Z - a}. \end{aligned}$$

Hence for large δ, $Y^I(\mathrm{S3}) > Y^L(\mathrm{S3})$.

PROOF OF LEMMA 5: *Step* 1. By Lemma 1, we write if $Y^L(\mathrm{S2}) \geq Y^w(\mathrm{S2})$ then from (12) and (13) $\dfrac{(\Pi - a) + \delta p2Z/(1-\delta)}{[1-\delta(1-p)]} - k \geq \dfrac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]}$. This can be written as

$$\begin{aligned} &\frac{\Pi + \delta p2Z/(1-\delta)}{[1-\delta(1-p)]} - k \\ &\quad \geq \frac{a}{[1-\delta(1-p)]} + \frac{\delta p\Pi}{1-\delta} + \delta(1-p)\left[\frac{(\Pi - a) + \delta p2Z/(1-\delta)}{[1-\delta(1-p)]} - k\right]. \end{aligned}$$

$\Rightarrow Y^L(\mathrm{S3}) \geq Y^I(\mathrm{S3})$ [with the help of (15) and (17)].

Step 2. Again by Lemma 1, if $Y^w(\mathrm{S2}) > Y^L(\mathrm{S2})$ then from (12) and (13)

$$\frac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]} > \frac{(\Pi - a) + \delta p2Z/(1-\delta)}{[1-\delta(1-p)]} - k.$$

$$\Rightarrow \frac{a}{[1-\delta(1-p)]} + \frac{p\delta\Pi/(1-\delta)}{[1-\delta(1-p)]} > \frac{\Pi + \delta p2Z/(1-\delta)}{[1-\delta(1-p)]} - k$$

$$\Rightarrow Y^I(\mathrm{S3}) > Y^L(\mathrm{S3}). \quad [\text{by (15) and (19)}]$$

Two steps taken together prove Lemma 5.

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