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Abstract

Transfers of technology to least developed countries (LDCs) are often hindered by lack of absorptive capacity on the receiving party, the possibility of imitation, and relatively thin markets for the licensed product. We propose a licensing model that considers these problems. A licensor must decide on the amount of know-how to costly transfer to the licensee, taking into account that this transfer may prompt the introduction of an imitation product. We study how this affects know-how transfers and the form of scheduled payments that support these transfers.

1 Introduction

Two important problems that firms in least developed countries (LDCs) encounter when accessing foreign technology are lack of absorptive capacity

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and weak protection of intellectual property rights. Lack of absorptive capacity implies that more intense efforts must be made to efficiently transfer a given technology. On the other hand, weak protection of intellectual property rights increases the likelihood of imitation, which may discourage the owner of the technology to transfer it to a LDC. these factors increase the transaction costs of technology transfer. Additionally, the potential market is often small in the case of LDCs. In fact, LDCs are typically characterized by a low average willingness to pay, and an unequal distribution of income, which dramatically reduces market size for many high-end products. This reduces the likelihood of North-South technological transfers taking place.

This paper proposes a licensing model that incorporates all these features. We analyze a firm's decision to license a new product technology to a firm located in a developing country. Know-how transfers from licensor to licensee reduce the licensee's production cost, but increase the likelihood of technological leakages to a third party. For instance, an employee of the licensee may absorb the new technology, come up with a version of the licensor's product that is adapted to the characteristics of the domestic market, and start up its own business. This, of course, is detrimental both to the licensor and to the licensee.

Regarding the structure of demand, we assume that only a fraction of consumers in the domestic country have a high willingness to pay for the licensor's product. These consumers constitute the relevant market for the product whose technology is being licensed. Consumers are ranked according to their respective income levels, and only consumers with relatively high income will have access to some complementary goods that provide them with additional value if consuming the product whose technology is being licensed. For instance, consider an electronic appliance that requires a stable source of power to work properly. Only consumers with access to such stable source of electricity -typically high-income consumers- will be willing to pay for the product, whereas the willingness to pay by low-income consumers will be much lower so that they never purchase the product.

If imitation is successful, the imitator introduces a good that is better adapted to the characteristics of the domestic country. For instance, an alternative appliance could be created which works even when there are oscillations in voltage, and with much simpler features. While this good is indeed regarded as inferior by all consumers, it is in fact more useful to those consumers which lack access to a complementary good such a stable source of electricity.

The transfer of know-how from the licensor to the licensee is costly, which will call for the right incentives for it to take place, specifically variable payments, as in Choi (2001). In his model, the role of variable payments is to mitigate the moral hazard problem on the licensor's side. In fact, if the contract stipulated fixed payments only, the licensor would not carry out any transaction-specific, non-contractible investment. Transferring a greater amount of know-how reduces the licensee's production cost, since the licensee has a deeper knowledge of the product technology in question. However, at the same time the transfer of know-how increases the likelihood of imitation.

In order to mitigate the moral hazard problem on the licensor's side, we expect the optimal contract to include both a fixed payment and a positive royalty whenever know-how is transferred. Fixed payment only contracts are expected when the licensor decides it is optimal not to transfer know-how. This is the case when the high-end market is small relative to the total.

The remainder of the paper is organized as follows. Section two describes the model, whereas section three introduces some concluding remarks.

2 The model

Consider a foreign licensor who owns a technology to produce a given product, henceforth the licensor's product, at a cost c. The licensor is considering licensing its technology to a firm in what we consider the domestic market. It could be the case that the licensor's product be imitated, giving rise to an imperfect substitute for the licensor's product. The total number of consumers in this market is normalized to to one, and consumers have unit demands for either the licensor's product or a substitute product that is an imitation of the licensor's product. Consumers are ranked according to their willingness to pay, which is ultimately determined by their income levels. In particular, there is a fraction of consumers, m, that have willingness to pay for the new product given by $p_1 = a_1(1 - q_1)$. On the other hand, the willingness to pay for the imitation is given by $p_2 = a_2(1 - q_2)$, with $a_1 > a_2$. The fraction m of consumers with a high-willingness to pay for the new product could be thought of as consumers with access to a complementary good that increase the value of using the licensor's product. It is assumed that only consumers with high income have access to this complementary good.

If the product technology is licensed, the licensor must decide on the amount of know-how to transfer to the licensee. The licensee's cost of producing the new product is $c(1-k)$, where $k \in [0,1]$ is know-how transferred by the licensor, at a cost (to the licensor) $\frac{\alpha k^2}{2}$. Since the level of know-how is not observable by a third party, the level of know-how transferred can not be contracted upon. The transfer of know-how has an unintended consequence, namely the possibility that the licensor's product be imitated, for instance by an employee of the licensee who starts up its own business after being exposed to the licensor's know-how. If imitation occurs a new entrant offers the imitation product, whose demand is given by $p_2 = a_2(1-q_2)$, at zero cost. Imitation occurs with exogenous probability $\gamma > 0$ whenever $k > 0$, and there is no imitation if $k = 0$. Hence, know-how is necessary for imitation to occur and the probability of imitation is independent of the amount of know-how transferred.

We thus propose a game with the following stages:

1. The licensor offers the licensee a contract (f, r) for the transfer of the product technology. The licensee accepts or rejects the contract.

2. If the licensee accepts, the licensor chooses $k \in [0,1]$. The probability of imitation is $\gamma \in [0,1]$ if $k > 0$, and zero if $k = 0$. If imitation takes place, the imitator's cost is zero, whereas the licensee's cost is $c(1-k) \geq 0$.

3. Firms choose prices p_1 and p_2. Production takes place, and payments are made.

As is usual in this type of games, we analyze the game backwards, thus starting from the production stage. We analyze the different stages of the game in the following subsections.

2.1 Production stage

In the final stage of the game, both contract terms, f and r, as well as the level know-how transfer, k, are fixed. Our goal is to characterize the licensee's output level as a function of k, m, and r. In doing so, we have to consider two alternative scenarios for the production stage, depending on whether or not imitation takes place. Recall that if $k = 0$, imitation occurs with probability one, whereas if $k > 0$, the probability of no imitation equals $1 - \gamma$.

Assume first that there is no imitation. Then the licensee is the sole producer in the market and thus chooses the monopoly price for the licensor's product, focusing on the high willingness-to-pay segment. Notice that if m is small enough, then the marginal revenue function is greater than the marginal cost at m, implying that the optimal output level is m. The monopolist would like to choose a lower price so as to expand output beyond m, but this is actually the relevant market size for its product. In other words, the market size constraint is binding. Therefore, the optimal price is:

$$p_1^M(k,m,r) = \begin{cases} a_1(1-m) \text{ if } m \leq \frac{a_1-c(1-k)-r}{2a_1} \\ \frac{a_1+c(1-k)+r}{2} \text{ if } m > \frac{a_1-c(1-k)-r}{2a_1} \end{cases}$$

The output levels associated with these prices are, respectively,

$$q_1^M(k,m,r) = \begin{cases} m \text{ if } m \leq \frac{a_1-c(1-k)-r}{2a_1} \\ \frac{a_1-c(1-k)-r}{2a_1} \text{ if } m > \frac{a_1-c(1-k)-r}{2a_1} \end{cases}$$

Now, if there is imitation, the licensee and the imitator compete in prices p_1 and p_2 respectively. Notice that the licensor's product is deemed superior by every consumer. However, access to complementary goods create the discontinuity in the demand function. The licensee will focus on the high willingness-to-pay consumers, whereas the imitator will target the low willingness-to-pay consumers. In order to compute market shares for the licensor's product and the imitation product, given prices p_1 and p_2, there will be an indifferent consumer $t(p_1,p_2)$ such that

$$a_1(1-t) - p_1 = a_2(1-t) - p_2$$

and this indifferent consumer will define the market shares of the two products such that

$$t(p_1,p_2) = \min\left\{1 - \frac{p_1-p_2}{a_1-a_2}, m\right\}$$

and the licensee's production level will be $q_1^I(k,m,r) = t(p_1,p_2)$. Consumers with highest willingness to pay will be purchasing from the licensee. In contrast, the imitator's output level will be $q_2^I(k,m,r) = 1 - \frac{p_2}{a_2} - t(p_1,p_2)$.

Then, the equilibrium prices if imitation takes place depend on whether the indifferent consumer is $t < m$ or $t = m$. In the latter case, the imitator chooses a price $p_2 = \frac{a_2(1-m)}{2}$, whereas the licensee's price is $p_1 = \frac{2a_1-a_2}{2}(1-m)$, making the consumer with willingness to pay for the licensor's product $a_1(1-m)$ just indifferent between purchasing the licensor's product and the imitation. Of course, the presence of the imitation effectively constraints the licensee's pricing behavior, forcing it to choose a lower price. In this particular case, the licensee's total output is $q_1 = m$, and the imitator's output is $q_2 = \frac{1-m}{2}$, so that total output is $\frac{1+m}{2}$. Notice that, in this case, the licensee's output is insensitive to changes in its marginal cost, a fact that directly influences the licensor's behavior when choosing how much know-how to transfer.

The other possibility is that the indifferent consumer is such that $t(p_1, p_2) < m$. This is the case when the proportion of consumers with access to complementary goods is large, i.e. m is high. In this case, the equilibrium prices are $p_1 = \frac{2a_1[a_1-a_2+c(1-k)+r]}{4a_1-a_2}$ and $p_2 = \frac{a_2[a_1-a_2+c(1-k)+r]}{4a_1-a_2}$. Thus, the level of output produced by the licensee if there is imitation is:

$$q_1^I(k, m, r) = \min\left\{\frac{(a_1-a_2)2a_1 - (2a_1-a_2)(c(1-k)+r)}{(a_1-a_2)(4a_1-a_2)}, m\right\}$$

which equals output sold by the licensee. Notice that the licensee's output decreases with its marginal cost, which depends on k and r, which have been defined in stages two and one, respectively. Also notice that the lower the value of m, the higher the probability that the licensee's output ends up being m.

2.2 Choice of know-how transfer

In the second stage, the licensor must choose $k \in [0,1]$ to maximize its expected profits in the production stage, given contract terms f and r. Recall that imitation occurs with exogenous probability $\gamma > 0$ if $k > 0$, and there is no imitation if $k = 0$. Notice that, in addition to influencing the probability of imitation, the licensor's choice of k has an effect on the licensee's marginal cost. Let $q_1^M(k, m, r)$ be the licensee's output if there is no imitation, and $q_1^I(k, m, r)$ be the licensee's output if there is imitation, as defined in the previous subsection. In the former case, the licensee faces no competition in the product market. This way, the licensor's problem in this stage may be written as

$$\begin{gathered}\max_{k\in[0,1]} r \cdot \left[(1-\gamma)q_1^M(r,k) + \gamma q_1^I(r,k)\right] - \tfrac{\alpha k^2}{2} \\ \text{s.t. } r \cdot \left[(1-\gamma)q_1^M(r,k) + \gamma q_1^I(r,k)\right] - \tfrac{\alpha k^2}{2} \geq r q_1^M(0, m, r)\end{gathered}$$

where $rq_1^M(0, m, r)$ are the licensor's net revenues if the licensor decides not to transfer know-how. This constraint points out the moral hazard problem on the licensor's side. Notice that choosing $k = 0$ implies that there is no imitation, that the licensee operates with a marginal cost equal to c, and that the licensor's costs of transferring know-how are zero. Thus, the constraint reflects the fact that, in order for the licensor to choose a positive transfer of know-how, its net revenues should exceed those if $k = 0$, which represents an inefficient production on the licensee's side, but also prevents imitation from occurring.

Now, if the solution is interior, i.e. if $k > 0$, it is characterized by

$$r \cdot \left[(1-\gamma) \frac{\partial q_1^M}{\partial k} + \gamma \frac{\partial q_1^I}{\partial k} \right] = \alpha k$$

where the signs of the partial derivatives are $\frac{\partial q_1^M}{\partial k} \geq 0$, $\frac{\partial q_1^I}{\partial k} \geq 0$, since the licensee's output never increases with its own cost.

This first-order condition implicitly defines an optimal $k(m, r)$. Consistent with standard moral hazard models, k is non-decreasing in r. Additionally, notice that a necessary condition for $k(m, r) > 0$ is that at least one of the partial derivatives be positive. In order for this to be the case, m has to be high enough, given r, otherwise the solution in both cases is such that the licensee produces an output level m, which is insensitive to variations in the marginal cost. In other words, if the constraint that the size of the high-end market represents is binding, the licensor does not have any incentives to invest in transferring know-how, and thus chooses $k = 0$. This occurs when the proportion of high willingness-to-pay consumers is relatively low.

The transfer of know-how, on the one hand, makes the licensee more efficient, but on the other hand, it makes imitation more likely. Additionally, the transfer of know-how is costly to the licensor, which will increase the likelihood of royalties being used in the licensing contract. Royalties are used to mitigate moral hazard on the licensor's side, since if the transfer involved a fixed fee only, then the licensor would optimally choose $k = 0$, a problem analyzed in Choi (2001). However, in our model there is an additional problem, which is the size of the high-end market, or the proportion of consumers with access to complementary goods. The licensor's incentive to transfer know-how depends crucially on the responsiveness of the licensee's output to cost reductions. If there is no response because the upper bound on market size is reached, the licensor will make no further investments in know-how transfers. Hence, given r, there will be a range of values $[0, \widetilde{m}]$ such that for $m \in [0, \widetilde{m}]$, the licensee chooses $k = 0$. Notice that $\widetilde{m}$ is non-increasing in r, since r raises the licensee's marginal cost, which has a non-positive effect on the licensee's output.

2.3 Choice of contract terms

In the first stage, the licensor must choose the fixed fee f and the royalty r to maximize its expected profits. The licensor must take into account the impact that its choice of r has not its own decision of how much know-how to transfer. This decision influences not only the licensee's marginal cost and the probability of imitation, but also the licensee's output choice, via variation in the marginal cost. When choosing f and r, the licensor must take into account the licensee's acceptance constraint, i.e. that its expected profits be greater than its outside option, which is assumed to be zero, for simplicity.

Bearing all this in mind, let $Eq_1(m, r)$ be the licensee's expected (at the beginning of the game) output, and let $E\pi_1(m, r)$ be the licensee's expected profits. Notice that r will determine k in the second stage, and thus the probability of imitation, as well as the licensee's marginal cost. Then, the licensor's problem at the initial stage reads

$$\begin{aligned} &\max_{f,r\geq 0} f + rEq_1(m, r) \\ &\text{s.t. } E\pi_1(m, r) - f \geq 0 \end{aligned}$$

Notice that the fixed fee allows the licensor to extract all of the licensee's profits, leaving it just indifferent between accepting and rejecting the licensor's offer. Therefore, the fixed fee is typically positive. Whether the royalty is also positive, and thus the contract stipulates a mixed payment scheme, depends on the size of the high-end market, m. For sufficiently high m, the royalty is positive and so is the transfer of know-how, k. Finally notice that a necessary condition for $k > 0$ is $r > 0$.

Specifically, taking into account that the constraint is binding and the licensor is able to reap all of the licensee's profits by means of the fixed fee, the licensor's problem may be written as

$$\max_{r\geq 0} E\left[\left(p_1(m, r) - c(1 - k(m, r))\right) q_1(m, r)\right]$$

Recall that k is a function of r and also of m, as studied in the previous subsection, and that k is non-decreasing in r. This way, there will be a threshold value of r, call it $\widetilde{r}$, such that for $r < \widetilde{r}$, then $k = 0$, and for $r \geq \widetilde{r}$, then $k > 0$. Then, the licensor's objective function, as a function of the royalty rate r, may be defined in two parts. In particular, for $r < \widetilde{r}$, there is no imitation, and the licensee's output and profits are as defined in subsection 2.1. Specifically, the licensor's objective function becomes $\left(p_1^M(0,m,r) - c - r\right) q_1^M(0,m,r)$, and if $r \geq \widetilde{r}$ so that $k > 0$, then the licensor's objective function may be written as

$$(1-\gamma)\left[\left(p_1^M(k(m,r),m,r) - c(1-k(m,r))\right) q_1^M(k(m,r),m,r)\right] +$$
$$+\gamma\left[\left(p_1^I(k(m,r),m,r) - c(1-k(m,r))\right) q_1^I(k(m,r),m,r)\right]$$

For a sufficiently low value of m, the licensee's optimal transfer of know-how is zero, and $q_1 = m$. Intuitively, if the high-end market is small enough, then a transfer of know-how has no market expansion effect, in the sense of increasing the licensee's sales. The transfer of know-how merely reduces the licensee's production cost. However, this is something that does not increase the licensor's variable revenues, which are sensitive to the licensee's output only, therefore it optimally chooses $k = 0$. Also notice that this makes the licensor indifferent between a fixed fee and a royalty. Finally, in this case royalties do not distort the licensee's output decision and have no effect on the licensor's moral hazard problem.

As m increases, the licensor has stronger incentives to transfer know-how and thus make the licensee's production more efficient. Thus, as countries develop and relatively more consumers are in the high willingness-to-pay group, production becomes more efficient, which should translate into higher welfare for these consumers. Not only that, but the probability of imitation increases with know-how transfers, benefitting consumers with lower willingness to pay. Thus, in our model economic growth increases expected consumer surplus in both consumer groups.

3 Conclusions

This paper has presented a model of technology transfer that allows for the possibility of imitation. In the model, imitation takes place as an unintended consequence of the transfer of know-how to a licensee. This know-how leaks outside of the licensee, for instance by means of worker's mobility, and permits the introduction of an imitation product, which steals market from the product that is being licensed. This reflects the situation common in many developing countries, of a small segment of the population with high income, which is able to consume goods similar to those in more developed countries, and a large segment of the population that lacks access to complementary goods that prevent those same goods from being consumed by the bulk of the population.

If the prime market is small relative to the total, then know-how is not transferred, which implies that, on the one hand, production is inefficient, and, on the other, that imitation does not take place. Welfare in the domestic country is lowest, since total output is minimized and all profits are transferred back to the foreign licensor. As the prime market grows, so do the licensor's incentives to costly transfer know-how, even at the cost of its own effort and at the added cost of potential imitation.

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