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Patent Protection, Innovation Rate and Welfare

Uday Bhanu Sinha

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Abstract: In the context of international technology transfer from the developed North to the developing South, this paper analyses the impact of the Southern patent protection on the innovation rate in the North and the welfare effect in the South. In a two-period model, we show how the different modes of technology transfers (licensing or subsidiary) affect the R&D incentive and thereby the rate of innovation in the North. It is shown that under the licensing contract, no patent protection in the South is best for the South as it increases the innovation rate in the North, thereby leading to greater welfare in the South. We also argue for certain degree of patent protection in the South for maximization of its welfare under some parameter configurations.

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Keywords: Technology transfer; Patent protection; Innovation; Welfare.

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1. Introduction

The issue of patent protection is one of the most contentious issues in the context of technology transfer from the developed North to the developing South. The developed countries mainly the United States, European Community and Japan feel that the present system provides an inadequate protection to intellectual property rights (IPRs) and are interested in strengthening this protection in the world. The poorer countries, on the other hand, are against this protection, as it would increase the profits of the monopolistic Northern firms at the expense of their domestic consumers.

The literature, in general, has tried to analyse this problem in the framework of a conflict of interest between the developed North and the less-developed South. The conventional economic reason underlying the conflict of interest between developed countries and developing countries is easy to see. The developed countries (North) are the major producers of newer technologies. The developing countries (South) are almost totally dependent on the North for technologies needed for their growth and development. Thus, the North would benefit from tighter patent protection in the South as this would protect the Northern firms against the imitators in their export markets. However, by the same token the South would like to pay as little as possible for these innovations, which is what lax patent protection achieves. This in turn reduces the incentives of the Northern firms to invest in R&D.

The important questions, however, are whether an increase in patent protection in the South leads to more innovation by the North and whether this increases the level of total welfare. The theoretical literature does not support the universal patent protection for a higher innovation rate and higher welfare in the world. In dynamic contexts, the issue of patent protection and its impact on the innovation rate and welfare are discussed by many authors (see Helpman (1993), Grossman and Helpman (1991), Segerstrom *et al*. (1990), Lai (1998) etc.).[1] Their findings seems to contradict the intuition furnished by Schumpeter (1942) and subsequently by Romer (1991), etc. that stronger patent protection should encourage

[1] In the first three papers, imitation is the only channel of international production transfer from North to South. Lai (1998) introduced the issue of foreign direct investment (FDI) with the modifications that Southern firms can imitate only after Northern firms transfer production to South. He concludes that stronger patent protection in the South increases the rate of product innovation if FDI is the channel of production transfer and has an opposite effect if production is transferred through imitation.

innovation. Deardorff (1991) argued for a case of limiting patent protection geographically rather than extending it universally across the world.

Chin and Grossman (1990) studied the welfare implications of patent protection in a North-South trading environment. In their model, global patent protection stimulates innovation in the North and thus the North benefits from the patent protection in the South. However, in their model, global welfare goes up or down depending on whether the productivity of Northern R&D is large or small. Diwan and Rodrik (1991) on the other hand, argue that when the North and South have different technological needs and tastes and the R&D resources are limited then the Southern patent protection might have a role in promoting the development of technologies appropriate to the South. They have also shown that increased patent protection in the South might not be good for the North, as more R&D resources would be deployed to suit Southern tastes.

All the above papers are concerned with technology diffusion and imitation, which takes place without any explicit transfer of technology between firms. In the context of technology transfer, Markusen (2001) noted that if tighter patent protection leads to a mode switch from exporting by multinational corporation to subsidiary operation, then the welfare of both the Northern firm and the host country (South) improves. On the other hand, if a subsidiary is chosen initially then tightening patent protection implies either no change or a fall in host country welfare. In the case of fall in host country welfare, the Northern firm earns more rent. Fosfuri (2000) analysed the mode of entry of Northern firms and the vintage of technology in terms of quality are influenced by the degree of patent protection in the recipient country. He showed that the welfare in the South is not a monotonic function of patent protection and both weak and strong patent protections are preferable to intermediate levels. In his model this happens because of the switch of modes of technology transfer with respect to the degree of patent protection.[2]

[2] It should be noted here that in Markusen (2001) technology transfer through a subsidiary creates an opportunity for the local agent to imitate the technology and thus, the local agent may "defect" to start a rival firm in future. On the other hand, in Fosfuri (2000), technology transfer under licensing facilitates imitation by the licensee and subsidiary production or exports circumvent imitation. Following Fosfuri (2000), we will assume that licensing facilitates imitation through a process of "learning by doing" in one period and subsidiary production does not allow imitation.

In a partial equilibrium framework we analyse the impact of patent protection on the innovation rate and welfare in the context of technology transfer. This paper is complementary to the papers by Markusen (2001) and Fosfuri (2000). We consider a strategic behaviour approach to the problem of technology transfer by a Northern firm to a developing country, where the Northern firm has the options of licensing or setting up a subsidiary. In case of licensing the technology to a Southern firm, there is the possibility of imitation by the Southern firm. The setting up of a subsidiary involves a set-up cost due to operating the business from across national and cultural boundaries (Hymer (1976)). However, contrary to Markusen (2001) and Fosfuri (2000), we endogenise the R&D activity of the Northern firm. We show how the different modes of technology transfers (licensing or subsidiary) affect the R&D incentive and thereby the rate of innovation in the North. It is shown that under certain parameter configurations, no patent protection in the South is best for the South as it increases the innovation rate and thereby leading to greater consumer surplus in the South. Although the innovation rate increases in response to a lowering of the degree of patent protection under the licensing contract but the payoff to the Northern firm goes down. We also argue for some degree of patent protection for the maximization of Southern welfare.

The rest of the paper is presented according to the following scheme. The next section presents the basic model with the assumption that there is no patent protection in the South. Section 3 deals with the issue of different degrees of patent protection. We conclude the paper in Section 4.

2. The Model

In a North-South framework, we consider a two-period model with no discounting. There is only one firm in the North, we call it a Northern firm. In the first period, the Northern firm possesses a technology (call it technology 1), which may be used to produce a particular product in the South. The Northern firm enjoys a patent in its home country (North) for technology 1 and is, therefore, the monopoly owner of technology 1. There are more than one firms in the South (call them Southern firms), who are willing to take the licence for this technology from the Northern firm. This technology is "drastic"[3] as compared to the

[3] A new technology is said to be 'drastic' when a firm with this new technology charges a monopoly price and the other firms with the older technology produce nothing (see Tirole, 1990).

domestically-available technology of the Southern firms. Technology 1 involves a particular constant marginal cost, which is a common knowledge. We assume that only the Northern firm can innovate a new technology in the first period in its R&D laboratory by incurring an expenditure *e*. However, the outcome of this innovation is uncertain. The Northern firm would be successful in innovation with probability *q(e)* depending on the R&D expenditure *e*. So the probability of the Northern firm's failure to innovate this new technology is (*1-q(e)*). *q(e)* is common knowledge to both the firms. This new technology (call it technology 2), if available, will be used only for the second period's production. Thus, in the second period, the Northern firm will decide either to license out technology 2 or to utilise that in the subsidiary production. For simplicity, we assume that these technologies are not used for the production in the North to serve the consumers there.[4]

We assume that technology 2 is 'drastic'[5] as compared to technology 1. Suppose Π_1 and Π_2 are one-period monopoly profits that can be generated by the Northern firm in the Southern market by utilising technology 1 and technology 2, respectively (obviously $\Pi_2 > \Pi_1$).

We have already assumed that the existing technology of the Southern firm is inferior as compared to that of the Northern firm at the beginning of the first period. The Southern firm can continue with its existing technology to earn its reservation payoff that, for simplicity, is taken to be zero in both periods. We also assume that the technology transfer is costless.

We assume that the contract cannot be written on future technology. That means, in the first period, no contract[6] can be contingent either on the success or failure of the R&D outcome of the Northern firm, or on technology 2, but a contract can always be written on present technology. Thus, in the first period the Northern firm cannot commit to provide technology 2 in the second period. However, in the second period, the Northern firm can write a contract to transfer technology 2, if it is available, once the Southern firm agrees on it.

[4] If these technologies are used for production for the Northern consumers also, then all the results of this paper hold with the additional consideration of the Northern profit and consumer surplus.

[5] This is assumed for the sake of simplicity. Our analysis will go through even with non-drastic technological progress.

[6] Our assumption of non-contractibility of future technology is in the same spirit as Aghion and Tirole (1994), who studied the organisation aspects of R&D activities and their implications in terms of frequency and size of innovations. They have used the incomplete contract framework and their assumptions were that the exact nature of the innovation is "ill defined" *ex-ante* and two parties cannot contract for delivery of a specific innovation.

To start off with let us assume that there is no patent protection in the South. We also assume that the technology transfer under licensing facilitates imitation without any cost through a process of "learning by doing" during production in the first period.[7] Due to this imitation, in the second period the Southern firm will have the necessary technical knowledge to carry out the production with technology 1 without depending on the Northern firm. On the other hand, when the Northern firm sets up a subsidiary it has to incur a set up cost F >0. We do not consider the option of serving the Southern market through exports since export is costly because of transport cost, tariff and the higher labour cost in the North.[8] When the market is served through the subsidiary production, the Southern firm cannot imitate the Northern technology.[9]

The structure of the game may now be set out.

First period: The Northern firm may either set up a subsidiary on its own or make an offer to license out technology 1 to the Southern firm. The Southern firm may either accept or reject the offer of licensing. When the Northern firm licenses the technology it charges an upfront fee T_1. After this decision, the Northern firm undertakes R&D to innovate technology 2 by incurring an expenditure *e*. The first period's profit is realised at the end of the period.

Second period: Suppose, in the first period the licensing contract has been accepted. In the second period, it can now offer to renew the licensing contract by charging a lumpsum fee. The Southern firm may either accept or reject the offer. If the offer is accepted, the Southern firm produces with the best available technology (either technology 1 or technology 2). However, after rejection, the Northern firm decides whether to enter with a subsidiary or not. In case the Northern firm has already set up a subsidiary in the first period, then in the second period it would continue with the subsidiary and serves the Southern market with the best available technology. The second period's profit is realised at the end of the period.

The second period licensing game can be depicted in Fig. 1 below.

[**Fig. 1 about here**]

[7] Our analysis would hold even with a low fixed cost of imitation.
[8] One can also consider the option of exports by the Northern firm to the South with some cost of exports along with the licensing and subsidiary options.
[9] See Fosfuri (2000) for a similar assumption.

The option of not renewing the licensing contract in the second period can be thought of as making an unacceptable offer, which gets rejected by the Southern firm and after that the Northern firm can decide whether to enter with a subsidiary or not. We assume that (a) the Northern firm enters if it gets a payoff which is weakly greater than no entry option; and (b) the Southern firm accepts the licensing contract when its payoff from acceptance is weakly greater than the payoff from rejection. Both parties are assumed to be risk neutral.

Note that the contract is binding only for one period. Thus, if the Southern firm does not renew the licence in the second period the Northern firm may enter with a subsidiary. In the second period, if the Northern firm enters with technology 2 then it would monopolise the Southern market. On the other hand, if the Northern firm enters with technology 1, there will be Cournot duopoly competition in the Southern market as the Southern firm can operate with technology 1 because of imitation. We denote Cournot duopoly profit under technology 1 by Π^d_1.

We specify the following:
(A1). *q(e)* is increasing and strictly concave in *e* with the property that *q(0) = 0* and *q(e) < 1* for any $e < \infty$, along with *q'(0)* being infinite.
(A2). $\Pi^d_1 - F > 0$.
(A3). $2\Pi^d_1 < \Pi_1$.
Assumption (A1) implies that there exists an interior probability value (between 0 and 1) for any positive level of R&D expenditure. The setting up of a subsidiary with technology 1 is feasible even when there is duopoly competition in the market. Assumption (A3) implies that monopoly profit is larger than the sum of duopoly profits under technology 1.

To find out the subgame perfect equilibrium of the game described above, we proceed through backward induction.

2.1 Second Period Game

We start out with the analysis of the second period outcome associated with the setting up of a subsidiary of the Northern firm in the first period. Suppose, the Northern firm is successful in innovating technology 2 in the first period. Now, in the second period the Northern firm

would introduce technology 2 in its subsidiary production. Thus, the Northern firm would receive the monopoly profit Π_2. In case the Northern firm is not successful in innovation, then it would have to operate the subsidiary with technology 1. Therefore, the Northern firm would receive the payoff Π_1. The Southern firm would receive 0 in both situations in the second period. Thus, we have the following outcome in the second period subgame.

Proposition 1. *Suppose the Northern firm sets up a subsidiary in the first period. If the Northern firm is successful in innovating technology 2, in the second period, the Northern firm would introduce technology 2 in its subsidiary operation and receives the monopoly profit Π_2. On the other hand, if the Northern firm is not successful in innovation, it produces with technology 1 in its subsidiary unit and receives the profit Π_1. The Southern firm receives zero in either situations.*

Consider the situation when the Northern firm has transferred technology 1 under licensing contract in the first period. Suppose, the Northern firm is successful in innovating technology 2 in the first period. If the Southern firm rejects the offer of renewing the licence in the second period then the Southern firm would receive zero, as the Northern firm would enter with a subsidiary to monopolise the market in the South. Therefore, the Northern firm can offer technology 2 to the Southern firm by charging an upfront payment Π_2 such that the Southern firm receives zero after accepting the offer of technology 2. This offer would be accepted by the Southern firm.

Now consider the possibility when the Northern firm is not successful in innovation. So, the Northern firm has technology 1. If the offer of renewing licence is rejected by the Southern firm, the Northern firm can set up a subsidiary to compete with the Southern firm (because of assumption (A2)). Since the Southern firm has also imitated technology 1, there will be Cournot duopoly competition between the subsidiary unit and the Southern firm's business. Thus, the Southern firm would receive the payoff Π_1^d after rejection and subsequent duopoly competition. Therefore, the Northern firm can make the offer of renewing the licence by charging $\Pi_1 - \Pi_1^d$ as fee such that the Southern firm receives Π_1^d, which is exactly what it receives after rejecting the offer. So the Southern firm would accept this offer of the Northern firm of renewing the licence.

Proposition 2. *Suppose the Northern firm has licensed out technology 1 in the first period. If the Northern firm is successful in innovating technology 2 in the first period, in the second period it offers to license out technology 2 with an upfront payment* Π_2*. The Southern firm accepts this offer and receives zero. On the other hand, if the Northern firm is not successful in innovation, it offers to renew the licence of technology 1 by charging* $\Pi_1 - \Pi_1^d$*. The Southern firm accepts the offer and receives* Π_1^d*.*

Note that in the second period outcome associated with the licensing in the first period, the Southern market will be served by the Southern firm either with technology 1 or technology 2. The Northern firm does not enter with a subsidiary in the second period equilibrium.

After having analysed above the outcome in different situations of the second period game, we move on to an analysis of the full game.

2.2 Full Game

In the first period, the Northern firm can either license out technology 1, or set up a subsidiary on its own. Suppose the Northern firm chooses to set up a subsidiary. Once the subsidiary is in place then in the first period, the Northern firm decides on how much R&D expenditure is to be made. This expenditure would depend on what the Northern firm expects to receive by undertaking R&D, which is (from Proposition 1)

$$q(e)[\Pi_2] + [1-q(e)]\Pi_1 - e \; ; \qquad (1)$$

where *e* is the expenditure on R&D and *q(e)* is the associated probability of successful innovation.

The Northern firm would choose R&D expenditure e^S to maximize the above payoff from its R&D. Thus, the first order condition implies

$$q'(e^S)[\Pi_2 - \Pi_1] = 1.^{10} \qquad (2)$$

Since the Northern firm has to incur a set up cost F for its subsidiary in the first period, the Northern firm would receive the payoff Π_1- F in the first period. Given the outcome in the second period (discussed in Proposition 1), the Northern firm's total two period's payoff is:

$$\Pi_1 - F + q(e^S)[\Pi_2] + [1-q(e^S)]\Pi_1 - e^S \qquad (3)$$

[10] Note that the second order condition for maximization is satisfied due to assumption (A1).

On the other hand, suppose the Northern firm decides to license out technology 1 in the first period. After signing this licensing contract, the Northern firm would decide on its R&D expenditure. The Northern firm would expect to receive by undertaking this R&D (from Proposition 2),

$$q(e)[\Pi_2] + [1-q(e)].\ [\Pi_1 - \Pi_1^d\ ] - e. \qquad (4)$$

Thus the Northern firm's choice of R&D expenditure under licensing contract e^L would be such that,

$$q'(e^L)[\Pi_2 - \Pi_1+\Pi_1^d] = 1. \qquad (5)$$

In the beginning of the first period, by accepting this licensing contract the Southern firm receives,

$$\Pi_1 + q(e^L).0 + [1-q(e^L)]\Pi_1^d - T_1, \qquad (6)$$

where T_1 is the license fee that is paid to the Northern firm in the first period.

The Northern firm receives the total payoff in two periods by offering the licensing contract in the first period

$$\Pi_1 + T_1 + q(e^L)[\Pi_2] + [1-q(e^L)]\ [\Pi_1 - \Pi_1^d\ ] - e^L.$$

The Northern firm would charge the fee optimally such that the Southern firm receives its two period reservation payoff, which is assumed to be zero. Thus, the Northern firm receives,

$$\Pi_1 + q(e^L)[\Pi_2] + [1-q(e^L)]\Pi_1 - e^L.^{11} \qquad (7)$$

Now by comparing the R&D expenditures under two different options given by condition (2) and (5), it is easy to see that the optimal R&D expenditure is greater under licensing (e^L) than under subsidiary (e^S). Thus,

Remark 1. *The innovation rate is higher under the licensing contract than under a subsidiary operation.*

Let us discuss the intuition of the above remark. Note that in the first period, the Northern firm can either set up a subsidiary or license out the technology 1. If it sets up a subsidiary in the first period then it would serve the market under monopoly through the subsidiary operation with the best available technology in each period. On the other hand, if the

[11] Note that the Northern firm receives the entire surplus that is available under licensing contract. This is because the Northern firm has all the bargaining power in the game.

Northern firm licenses out technology 1 in the first period then in the second period it receives the same payoff as in subsidiary operation in case it is successful in developing technology 2. However, it receives strictly lower payoff under licensing than under subsidiary in case it is not successful (see Propositions 1 and 2). Note that the Northern firm's R&D expenditure depends on the premium it receives after being successful which is over and above what it receives when it fails to innovate. As a result, the Northern firm's R&D incentive is higher under licensing contract than under a subsidiary in the first period. Therefore, the innovation rate, i.e. the probability of successful innovation is higher under licensing contract. The crucial point to note is that under licensing, the Northern firm is pre-committing itself to a lower payoff in case of failure in innovation leading to a higher R&D expenditure in the first period.

Now by comparing the payoffs from the option of subsidiary and licensing we have the following outcome of the two period game.

Proposition 3. *If* $F \geq [q(e^S) - q(e^L)][\Pi_2 - \Pi_1] + e^L - e^S$ *, the Northern firm chooses to license out technology 1 in the first period. Otherwise, the Northern firms sets up a subsidiary in the first period.*

Thus, when the setup cost of the subsidiary is high, the Northern firm opts for a licensing contract in the first period, however, if the setup cost is low then the Northern firm opts for a subsidiary in the first period.

3. Patent Protection

Note that the above analysis is carried out with the assumption that there is no patent protection in the South. We now discuss what happens if we introduce different degrees of patent protection in our analysis. Suppose, there is perfect patent protection in the South. Then the legal system or court of the South would debar the Southern firm to use technology 1 in the second period without the renewal of the licence. In that case, the Southern firm cannot use the technology 1 in the second period after imitating it during the first period production. So, the Southern firm has to depend on the Northern firm in the second period

even for technology 1. This implies that the reservation payoff of the Southern firm is zero in the second period. In this case the Northern firm would offer the best technology available in the second period and charge the upfront fee appropriately such that the Southern firm receives zero in the second period. Thus, even if the Northern firm is unsuccessful in innovation it can receive Π_1. Therefore, the innovation incentive under licensing contract would be the same as under subsidiary operation given by (2). Thus, the R&D expenditure would be the same for both licensing and subsidiary options leading to the same innovation rate. However, the Northern firm would choose licensing contract in the first period because of the setup cost F for a subsidiary, which is assumed to be positive.

Now suppose that the patent protection is less than perfect. We assume that the Southern firm can imitate the first period technology without any cost, but there is a positive probability, γ, that the local court in the South, in the beginning of the second period, will be able to detect the imitation and debar the Southern firm from using it in the second period (where $0<\gamma<1$).[12] On the other hand, if the imitation is not detected by the Southern court, the Southern firm can continue its production with the imitated technology. Thus, the Southern firm will be able to use the first period technology in the second period with probability $(1-\gamma)$. So, the Southern firm would have reservation payoffs in the second period either 0 or $(1-\gamma)\Pi^d(c_1)$, depending on whether the Northern firm is successful in innovation or not. Thus, from (5) we find that the R&D expenditure under licensing contract would be,

$$q'(e^L)[\Pi_2 - \{\gamma\Pi_1 + (1-\gamma)(\Pi_1 - \Pi_1^d)\}] = 1. \qquad (8)$$

Note that γ measures the degree of patent protection in the present set up. The patent protection becomes weaker as γ decreases. Now it is obvious from the above condition that the R&D expenditure (e^L) would be higher, the lower the γ is, i.e., the lower the patent protection is. Thus, the innovation rate would be the highest when there is no patent protection in the South. Thus, we have found an inverse relationship between the patent protection in the South and innovation rate in the North.

[12] We are assuming away any cost associated with the filing of application to the local court such as court fee and payment to lawyers for both parties. Also we rule out any penalty imposed by the court on the Southern firm in case the imitation is detected except that the court forbids the Southern firm to use that technology without the renewal of licence.

The welfare in South is only dependent on consumer surplus since the Southern firm receives zero in the two periods under licensing contract. The consumer surplus depends on the probability of introducing the better technology in the South. Therefore, the consumer surplus and degree of patent protection varies inversely and the Southern welfare is maximum when the South has no patent protection at all. Also note that the Northern firm's payoff is higher when the patent protection is higher. However, the above implications of patent protection hold only if the Northern firm chooses the licensing contract as opposed to subsidiary operations. Now the Northern firm would choose licensing contract only when $F \geq [q(e^s) - q(e^L)][\Pi_2 - \Pi_1] + e^L - e^S$ at $\gamma = 0$ (from Proposition 3). Thus,

Remark 2. *Suppose, $F \geq [q(e^s) - q(e^L)][\Pi_2 - \Pi_1] + e^L - e^S$ at $\gamma = 0$. The lower is the patent protection in the South, the higher is the innovation rate in the North and the greater is the welfare in the South and lower is the payoff for the Northern firm.*

Therefore, the optimal patent protection for the Southern government is to choose $\gamma = 0$. Now suppose $F < [q(e^s) - q(e^L)][\Pi_2 - \Pi_1] + e^L - e^S$ at $\gamma = 0$, this means that the Northern firm would choose subsidiary if the degree of patent protection is zero. Since the RHS is a decreasing function of γ (due to Eqn. (8)), so the Southern government can optimally choose γ^* such that $F \geq [q(e^s) - q(e^L)][\Pi_2 - \Pi_1] + e^L - e^S$ at γ^* thereby making the licensing as a superior option over subsidiary for maximizing welfare in the South. Thus, we find an optimal degree of patent protection for the South also.

4. Conclusion

To sum up, this paper is a contribution to the ongoing debate on patent protection in the context of technology transfer from the North to the South. In a partial equilibrium framework this paper analyses the impact of the Southern patent protection on the innovation rate in the North and on welfare of the world as a whole. In a two period model, we have considered that a Northern firm having a new technology can choose between licensing and subsidiary as modes of entry to the South in the first period. The Northern firm also develops a better technology in the first period, which can be used for the second period's production in the South. We establish that when the Northern firm licenses out the first period

technology to a Southern firm located in the South, the lower is the degree of patent protection in the South, the higher is the innovation rate in the North and the higher is the welfare in the South. We also find an optimal degree of patent protection for the South, which may be zero or some positive degree depending on the parameter configurations. Therefore, the paper demonstrates that the debate on patent protection must take into account the different aspects of R&D organization and the enforcement of different contract laws to make any policy prescription related to patent protection.

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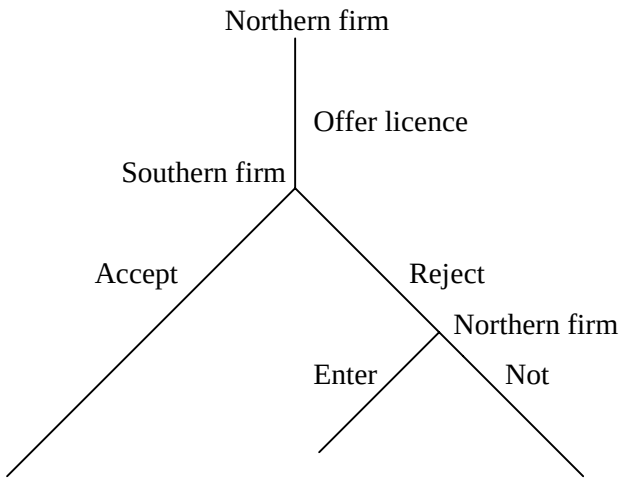

Fig. 1. Second period licensing game.