International Technology Transfers and Competition

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Abstract

This paper analyzes North-South technology transfers in a model of oligopolistic competition. Two firms in the North supply a high-tech good and a technically related low-tech good. They decide about licensing the low-tech good to low-cost suppliers in the South. With the license Southern firms get access to technology from the North which enables them – with a certain probability – to enter the market for the high-tech good. Firms of the North then face a trade-off between additional profits in the low-tech segment and additional competition on the high-tech end of the market. In this setting, multiple equilibria with and without licensing may arise and the resulting outcomes may be inefficient from the viewpoint of the firms in the North.

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1 Introduction

International activities of private companies are a major source for technology transfers across national borders (see e.g. Reddy and Zhao 1990, Keller 2004, or Maskus 2004). Through a variety of channels – trade, foreign direct investment, or contractual agreements such as outsourcing or licensing – firms from technologically lagging countries get access to technology from more advanced nations. One important issue is how these technology transfers influence the competitive position of firms in the different countries. In particular, firms from less-advanced regions may emerge as new competitors in profitable high-tech markets if the technology gap to the established firms from more advanced countries narrows. This possibility seems to be widely recognized among decision makers of the technology-sending firms. For example, according to a study by Bennett et al. (2001), the majority of managers of EU-firms engaging in technology transfers to China acknowledges the capacity of their Chinese partners to absorb, use and replicate technologies and to become a "competitive threat" only a few years later.

This paper deals with the consequences of technology transfers for the decision of firms to license their technology internationally. More specifically, we consider oligopolistic firms in a highly developed North which can license a low-tech good to a less developed South. Foreign production reduces production costs,[1] but it also transfers technology to the contract partners in the South. The partner firms from the South may use this technological know-how not only to supply the contracted good but also to enter a more profitable high-tech market where Northern firms are active as well. Thus, Northern firms may bring up their own competitors from the South by transferring technology.

It follows that firms deciding upon licensing face a trade-off: On the one hand, they can make higher profits from the low-tech good, but on the other hand the technology transfers increase the expected degree of competition in the high-tech market. A recent example is the industry for Light Emitting Diodes (LEDs). The "big five" industry leaders[2] have a proven track of licensing agreements with low-cost manufacturers in Asia (Strategies Unlimited 2005). These licensing contracts allow to save production costs in highly competitive and large market segments such as background displays for mobile phones. Meanwhile, some of the licensing partners have managed to surmount the gap to serve so called "high-tech, high-spec" market segments such as for automobile supply or computer displays, and emerge as new competitors in these fields.

Analyzing the interplay between oligopolistic rivalry in the one market and the decision to license in the other, we obtain a couple of interesting results: First, strategic interaction between Northern firms leads to technology transfers even in cases where they certainly reduce the firms' expected aggregate prof-

[1] See e.g. Vernon and Davidson (1979), Hobday (1995), Bennett et al. (2001), or ITEM/TECTEM (2005).

[2] Nichia Corporation (Japan), Toyoda Godei (Japan), Lumileds (USA), Cree (USA), and Osram (Germany) together hold a combined share of 86% of the market for high-brightness LEDs based on GaN-material (in 2003).

its. This result is surprising because we assume that the Northern firms can completely extract the expected profits of the Southern firms by selling licenses with take-it-or-leave-it offers. As a consequence, Southern firms just break even in expectation, so that the result has nothing to do with a redistribution of profits from the North to the South. Second and related, we find that licensing may be a subgame perfect equilibrium (SPE) even if it has no influence at all on the production costs in the low-tech market. Instead, a purely strategic motive for licensing results from the interaction between firms in the high-tech market. Third, we show that multiple equilibria may arise, leading to outcomes with and without licensing from the same initial conditions. This may help to explain why more or less similar industries may end up in very different market constellations.

Existing related papers on technology transfers resulting from international production mainly focus on the role of technology diffusion in the South. Pack and Saggi (2001) show that the diffusion of transferred technology in the South can be beneficial even though it may induce the emergence of new competitors. In their model a firm in the North decides about outsourcing to the South. The outsourcing firm transfers technology which may dissipate to other potential suppliers in the South. The technology spill-over has two pro-competitive effects on the market outcome: On the one hand, it limits market power of the outsourcing partner in the South. On the other hand, it may induce entry by competitors in the North. Both effects can help to lessen a double marginalization problem which otherwise causes inefficiently high prices. Goh (2004) extends the model of Pack and Saggi (2001) allowing for endogenous efforts of low-cost suppliers to absorb the technological capacity and distinguishes between upstream and downstream knowledge diffusion.

In van Long (2005) a firm from a high-wage country competes with a firm from a low-wage country in a Cournot-duopoly. The high-wage firm can outsource part of its production to the low-wage country. Technology diffusion then may reduce costs of the competitor in the low-wage country. Because of this spill-over, the high-wage firm may choose to outsource only a part of its production. In Stähler (2006) there are two firms in the North and no rival firm in the South. Again, technology diffusion lowers the competitor's costs. In this setting Stähler (2006) analyzes the decision between outsourcing with technology spill-overs and FDI without spill-overs but with additional fixed costs from setting up a foreign plant.[3]

In contrast to these papers, technology spill-overs between different firms in the South are not the driving force of our results. To highlight this, we exclude them altogether from our analysis, assuming that the technology transferred does not benefit other firms than the Southern licensing partner itself. However, because of contractual incompleteness, the Northern firm can not prevent that the Southern partner uses the technology for other purposes than to supply the licensed low-tech good – instead, it may enter the profitable high-tech

[3]Kabiraj and Marjit (2003) and Mukherjee and Pennings (2006) consider the interplay between trade policy and international technology transfers.

market. Furthermore, contrary to Pack and Saggi (2001), we do not aim at explaining why Northern firms may benefit from technology transfers even though it increases competition, but rather why these technology transfers can be an inefficient SPE from the Northern firms' viewpoint even if all expected profits in the South can be transferred *ex ante* to the North by up-front licensing fees.

The paper is organized as follows: Section 2 sets up the model. Section 3 derives the non-cooperative equilibrium with respect to the licensing decision. Section 4 considers the cooperative solution, and section 5 concludes.

2 The Model

Consider two firms ($i = 1, 2$) located in the North. Each firm supplies two goods, a low-tech good L and a high-tech good H. Demand for both goods is characterized by Salop-type horizontal product differentiation. Firms are located equally on the circumference of a unit circle, and consumers are distributed uniformly around the circle. The circle represents possible product types, and consumers have preference costs t (in the low-tech market) and τ (in the high-tech market) for each unit of distance between their position and the position of the supplier on the circle. Competition from outside restricts the market power of the suppliers in the low-tech market: Consumers buy the good only if its price plus preference costs is below a given reservation price $\bar{p}$ offered by outside competitors. In the high-tech market, in contrast, there are no outside competitors, and each consumer buys one unit of the high-tech good from one of the suppliers. This specification allows us to capture the fact that competition from (additional) outsiders plays a higher role in markets for commodities. It also simplifies the analysis, but we expect all our results to go through if we allow for strategic interaction in the low-tech market.

The link between licensing in the low-tech market and competition in the high-tech market is given by ρ which measures the probability that a Southern licensing partner enters the high-tech market. In the basic model (see our concluding remarks, however), we assume that entry probabilities ρ of these two firms are identical but uncorrelated. Since there are two firms in the North, we have two potential competitors in the South. Thus, there may be the situation of a triopoly (one supplier from the South and two from the North) or even a quadropoly (two suppliers from the South and two from the North) instead of the duopoly in the market for the high-tech good.

The game is as follows: In stage 1, both firms in the North simultaneously decide about licensing the low-tech good to the South. In stage 2, nature decides about the number of firms in the high-tech market, and in stage 3 firms compete in the high-tech market. Applying backward induction, we start with the high-tech market.

2.1 High-Tech Market

Figure 1a shows the situation for the high-tech good with only the two Northern firms in the market.

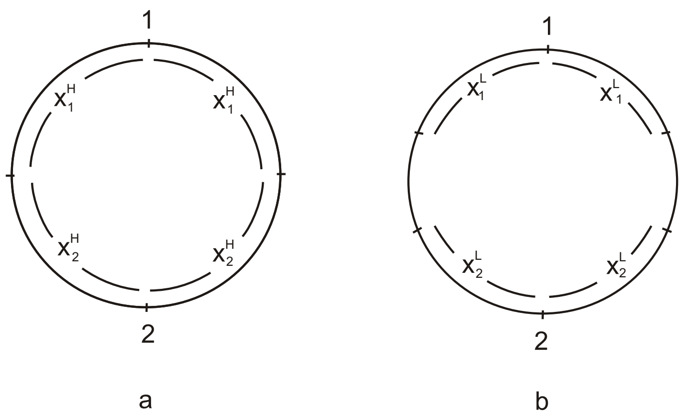

Figure 1: High-Tech and Low-Tech Market

The market area of each firm is determined by $p_i^H + \tau x_i^H = p_j^H + \tau(1/2 - x_i^H)$, where $j \neq i$. We therefore obtain an individual demand function $q_i^H = 2x_i^H$ for the high-tech good of $q_i^H = 1/2 + (p_j^H - p_i^H)/\tau$. We normalize marginal costs in the high-tech market to zero.[4]

The profit maximizing price is $p_i^H = \tau/2$, and the duopoly profit of each firm π_i^{H2} is

$$\pi_i^{H2} = \frac{\tau}{4}.$$

The situation with three and four firms is equivalent to the case of a duopoly. We assume that the cost advantage of the South only refers to producing the low-tech good, i.e. marginal costs for the high-tech good are also zero for the firms from the South. The respective profit levels with three and four firms are then

$$\pi_i^{H3} = \frac{\tau}{9} \qquad \text{and} \qquad \pi_i^{H4} = \frac{\tau}{16}.$$

[4]This implies (i) that marginal costs in the high-tech market are lower than those in the low-tech market and (ii) that Northern and Southern firms have the same marginal costs in the high-tech market. At least the first assumption is counterfactual, but it is straightforward that dropping these assumptions only complicates our analysis by producing additional terms in the profit function without offering additional insights.

We see that technology transfers have an indirect effect in the market for the high-tech good since an increase in the number of firms lowers profits per firm.

2.2 Low-Tech Market

Figure 1b depicts the situation in the market for the low-tech good. Firm i serves a market of $q_i^L = 2x_i^L$, where x_i^L is given by $p_i^L + tx_i^L = \bar{p}$. From this equation, we can derive the demand function for the low-tech good supplied by firm i as $q_i^L = 2(\bar{p} - p_i^L)/t$. We assume the given reservation price $\bar{p}$ is so low that the market areas of both firms do not overlap. Then, there is no strategic interaction between firms in the low-tech market. With marginal costs of c_i $(0 \leq c_i < \bar{p})$ firm i charges a price $p_i^L = (\bar{p} + c_i)/2$ and makes a profit of

$$\pi_i^L = \frac{(\bar{p} - c_i)^2}{2t}.$$

Firms can either produce the low-tech good in the North with marginal costs $c_i = c$ or they can license the good to the South. Firms in the South have lower production costs for the low-tech good. To capture their cost advantage, we set the marginal costs under licensing equal to zero. The licensing contract gives the partner firm from the South the exclusive right to supply the low-tech variety i, such that the firm from the North ceases to produce this variety.[5]

Profits in the low-tech market with licensing (π_0^L) and without licensing (π_c^L) are

$$\pi_0^L = \frac{\overline{p}^2}{2t} \qquad \text{and} \qquad \pi_c^L = \frac{(\overline{p} - c)^2}{2t},$$

respectively. With a cost advantage of the South $(c > 0)$, licensing raises profits that can be made in the low-tech market.

3 Licensing Decisions in the Non-cooperative Equilibrium

Because of potential market entry in the high-tech market a strategic relationship exists between the licensing decisions of both firms. Given the expected profits in the various Nash-Equilibria with (partial) entry in the high-tech market, and the profits in the low-tech market with and without technology licensing, we can now solve for the SPE of the total game.

In the first stage of the model both firms in the North decide simultaneously about international licensing. We assume a large number of potential licensing partners in the South all with set-up costs and marginal production costs of zero. Each Northern firm can charge an up-front fee for the licensing contract and give the contract to the highest bidder.In equilibrium, Northern firms set the fee high enough to skim off all rents resulting from the contract. In other

[5] Assuming instead that the Northern firm stays in the market after licensing the good to the South would not change our results in a qualitative way.

words, the up-front fee transfers the expected profit of the firms from the South to the firms in the North. We introduce this assumption to highlight that in our model, the result that technology transfers may reduce the profits of the firms in the North has nothing to do with a re-allocation of profits from the North to the South.[6]

With technology licensing by both firms, the total expected profit Π_{SS} for each firm in the North is

$$\Pi_{SS} = \frac{\overline{p}^2}{2t} + \rho^2 \frac{\tau}{8} + \rho\left(1-\rho\right)\frac{2\tau}{9} + \rho\left(1-\rho\right)\frac{\tau}{9} + \left(1-\rho\right)^2 \frac{\tau}{4}.$$

The first term in this equation is the profit in the low-tech market. The other terms denote the expected profits for a Northern firm and its Southern licensing partner in the high-tech market. For example, with probability ρ^2 two Southern firms enter, yielding a profit of $\pi_i^{H4} = \tau/16$ per firm. This yields an expected profit of $\rho^2\tau/8$. The other components in Π_{SS} can be explained in a similar fashion. Note again that we can simply add up the profits of the firm in the North with its Southern partner as these are extracted by the licensing fee. Rearranging the above equation leads to

$$\Pi_{SS} = \frac{\overline{p}^2}{2t} + \frac{\tau}{4} - \rho\frac{\tau}{6} + \rho^2\frac{\tau}{24}.$$

Without licensing the expected profit of each firm in the North is

$$\Pi_{NN} = \frac{\left(\overline{p}-c\right)^2}{2t} + \frac{\tau}{4}.$$

If a firm is the only one engaged in licensing, its expected profit is

$$\Pi_{SN} = \frac{\overline{p}^2}{2t} + \rho\frac{2\tau}{9} + \left(1-\rho\right)\frac{\tau}{4},$$

while the other firm in the North expects a profit of

$$\Pi_{NS} = \frac{\left(\overline{p}-c\right)^2}{2t} + \rho\frac{\tau}{9} + \left(1-\rho\right)\frac{\tau}{4}.$$

This given, we can now derive the set of SPE. A symmetric SPE with licensing by both firms exists if and only if $\Pi_{SS} - \Pi_{NS} \geq 0$ or

$$\frac{\rho^2\tau}{24} - \frac{\rho\tau}{36} + \frac{c\left(2\overline{p}-c\right)}{2t} \geq 0. \tag{1}$$

A symmetric equilibrium without licensing exists for $\Pi_{NN} - \Pi_{SN} \geq 0$ or

$$\frac{\rho\tau}{36} - \frac{c\left(2\overline{p}-c\right)}{2t} \geq 0. \tag{2}$$

[6]See, however, our discussion in the concluding section.

We immediately see from (1) and (2) that at least one of these expressions is satisfied as a strict inequality. Thus, a symmetric equilibrium always exists. Note that this also precludes the existence of an asymmetric equilibrium since a necessary condition for an asymmetric equilibrium is that $\Pi_{SS} - \Pi_{NS} \leq 0$ and $\Pi_{NN} - \Pi_{SN} \leq 0$ hold simultaneously.

For an interpretation of the equilibrium conditions (1) and (2), let us first consider the case $c = 0$. In this situation production costs in the low-tech market are the same in the North and in the South such that at first sight technology transfers do not seem to make sense at all. Consequently, with $c = 0$ inequality (2) simplifies to $\rho t/36 \geq 0$. This condition is always satisfied, so that an equilibrium without licensing always exists. There are no cost advantages in the low-tech market to benefit from in this case, and the only effect from licensing is the possible competition in the high-tech market. Since $2\pi_i^{H3} = 2\tau/9 < \tau/4 = \pi_i^{H2}$, market entry by the partner firm from the South lowers profits of the Northern firm although the North can extract all rents from this market entry in advance. Thus, a Northern firm has no incentive to license if its competitor does not do so.

However, for $\rho^2\tau/24 \geq \rho\tau/36$ or $\rho \geq 2/3$ an additional symmetric equilibrium exists where both firms do engage in licensing. This equilibrium arises from the fact that $2\pi_i^{H4} = \tau/8 > \tau/9 = \pi_i^{H3}$. If the partner of the competitor firm enters the market, it is better for the Northern firm that an own licensing partner also enters the market, since the aggregate profit earned by two firms in a market with four oligopolists exceeds profits of one firm in a market with three. This strategic effect becomes more important for high ρ, i.e. for a high probability of foreign market entry. Then the best response to licensing by the competitor firm is to license as well. The dilemma situation for the Northern firms can thus best be characterized by considering the impact of ρ: The higher ρ, the higher is the expected degree of competition, the lower are aggregated profits in the North in a licensing equilibrium. However, due to the strategic interaction, incentives to license are also increasing in ρ.[7] Summarizing the case $c = 0$, we have a unique SPE with no licensing by both firms if $\rho < 2/3$. For $\rho \geq 2/3$, the model has two symmetric SPE, one with and the other without licensing.

For $c > 0$, licensing has the additional effect of saving costs in the low-tech market. In this case, we first see from (2) that the equilibrium without licensing ceases to exist for very small ρ, i.e. for $\rho\tau/36 < c\,(2\overline{p} - c)\,/2t$. In this case, inequality (2) is violated. If the probability of market entry by southern firms is sufficiently low, then cost-savings from licensing dominate the potential competition from Southern firms in the high-tech market. An equilibrium with licensing exists in this case as (1) is satisfied as a strict inequality.

Figures 2 and 3 illustrate the existence conditions for the case $c > 0$. The line x depicts the expression $\rho\tau/36 - c\,(2\overline{p} - c)\,/(2t)$ of (1) and (2) as a function of ρ. Curve y is given by the additional term $\rho^2\tau/24$ of (1). Inequality (2) is

[7]In the concluding section, we discuss the case of different ρ's and consider the influence of the own probability and the rival's probability separately.

then given by $x \geq 0$ and (1) by $y - x \geq 0$. To the right of point A, where $x \geq 0$, the model has an equilibrium without licensing. In Figure 2 x and y intersect twice (at B and C). An equilibrium with licensing exists to the left of B and to the right of C, where $y - x \geq 0$ and inequality (1) is satisfied. Thus, starting from $\rho = 0$, the model switches between an equilibrium with licensing (to the left of A), two equilibria (between A and B), an equilibrium without licensing (between B and C), and, again, two equilibria (to the right of C).

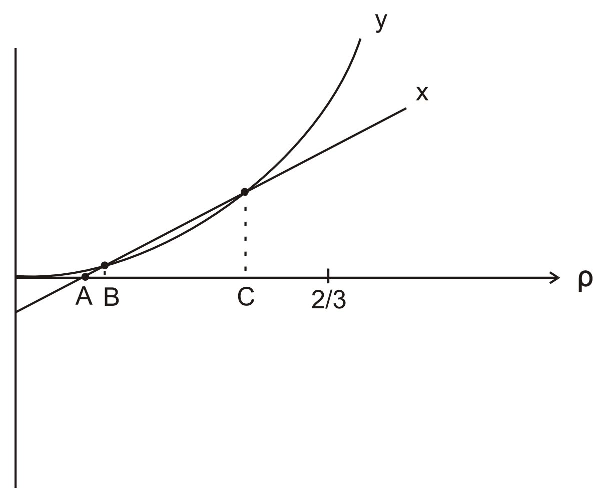

Figure 2: Equilibria of the Technology Transfer Game, Case I

In Figure 3 x and y do not intersect.[8] Then, the licensing equilibrium exists for all ρ. An additional equilibrium without licensing can exist only if the intersection point A implies $\rho \leq 1$. Otherwise the non-cooperative game has a unique symmetric SPE with licensing.

With the help of these figures we can do some comparative statics. For example, an increase in c raises the cost advantage of the South relative to the North. Line x then shifts downwards, increasing the parameter range for which a licensing equilibrium exists. The same holds for an increase in the reservation price $\bar{p}$. Thus, interestingly, more competition in the low-tech market (a reduction in $\bar{p}$) makes licensing less attractive for Northern firms. The reason is that the rent that can be earned in the low-tech market declines whereas the costs of licensing, resulting from the technology transfer, remain unaffected by $\bar{p}$. An increase in t, the preference costs for the low-tech good, shifts the x-line upward and makes technology licensing less attractive.

[8] Of course, we may also have a situation where x is tangent to y with similar results as in figure 3.

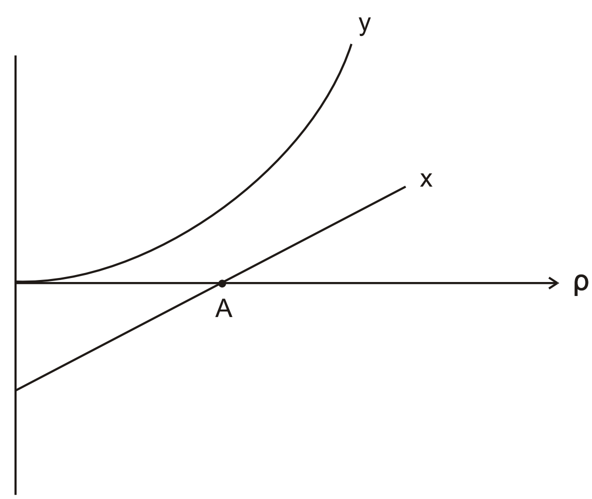

Figure 3: Equilibrium of the Technology Transfer Game, Case II

4 Cooperative Situation

As a benchmark for a comparison to the non-cooperative equilibria this section derives the cooperative solution of the model. This cooperative solution maximizes joint profits of both Northern firms. First of all, as in the non-cooperative case, we can neglect asymmetric allocations where only one firm licenses its low-tech good. Such a situation does not maximize joint profits (see appendix). We are therefore left with comparing licensing by both firms with the no-licensing case. Licensing is profitable for both firms if the following inequality is satisfied:

$$\Pi_{SS} - \Pi_{NN} = \frac{\rho^2 \tau}{24} - \frac{\rho \tau}{6} + \frac{c\,(2\bar{p} - c)}{2t} > 0. \tag{3}$$

Comparing (3) with (1) shows that inequality (1) is weaker than (3). A licensing equilibrium may therefore exist although it reduces the profit of both firms compared to the situation without licensing.

This becomes most clearly if we again begin with the case $c = 0$. Then inequality (3) cannot be satisfied.[9] Thus, the licensing equilibrium, which exists for $\rho \geq 2/3$ in this case, is associated with lower aggregate profits compared to the equilibrium without licensing. The intuition for this result is straightforward: If production costs in the North are the same as in the South, licensing does not save costs in the low-tech market. The only effect of licensing is

[9]This follows from the fact that (3) requires $\rho > 4$ for $c = 0$, which is outside the feasible range of $0 < \rho < 1$.

the potential erosion of profits in the high-tech market resulting from entry by Southern firms.

For $c > 0$ licensing has an additional, cost saving effect. In this case, if cost savings are high enough and/or if the probability of Southern entry ρ is low enough, licensing may raise aggregate profits. However, we may also obtain a SPE with licensing that is inefficient. Figure 4 provides an illustrative example. It depicts a situation where line x intersects the abscissa to the right of $\rho = 1$. In this case, inequality (2) can not be satisfied and the model has a unique SPE with licensing for all ρ. Line x' represents the term $\rho t/6 - c\,(2\bar{p} - c)\,/\,(2t)$ from inequality (3). To the left of intersection point B' with curve y the licensing equilibrium is efficient, i.e. it maximizes aggregate profits of both Northern firms. To the right of B', however, both firms would be better off without licensing.

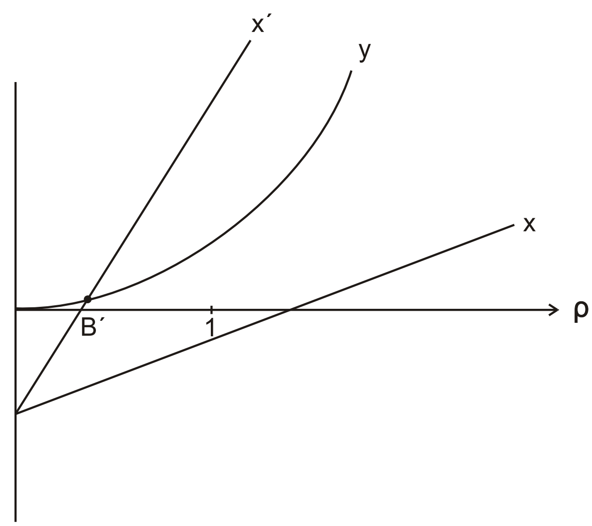

Figure 4: Example for Inefficient Technology Licensing

5 Conclusion

Even though our model is quite simple, it provides a couple of interesting insights regarding the potential competitive effects of international technology licensing. We have seen that *(i)* multiple equilibria may exist in this setting, *(ii)* licensing may occur although no cost savings can be expected from it, *(iii)* a licensing equilibrium may exist for low and high probabilities of market entry by the South, and that *(iv)* licensing equilibria may be inefficient from the Northern firms' point of view even though the firms in the South do not earn positive profits in expectation.

Some of our simplifying assumptions, however, demand further discussion. First, we have assumed that firms from the North can channel the total expected profits into their pockets. If there are only a few potential licensing partners in the South and if competition between them is incomplete, then it may be possible that the South also retains some profits from licensing. To account for this possibility, we have also analyzed an alternative setting where the licensing fee only covers the profits from supplying the low-tech good but not those that can be expected from entering the high-tech market. In this case, the expected profit from licensing decreases for both Northern firms. As a consequence, the condition for an equilibrium with technology transfers becomes stronger compared to (1) and the condition for an equilibrium without becomes weaker compared to (2). However, for positive c the qualitative results of our paper do not change: We can characterize the SPE of our model in a similar fashion as in figures 2 and 3.

Second, we have seen in section 3 that a licensing equilibrium becomes more likely if the probability of market entry ρ increases. Thereby, however, we have assumed ρ to be identical for both firms. The influence of the probability of market entry could therefore not be analyzed separately for the own Southern partner and the rival's partner. To allow for this, we have also considered a model with different ρ's. The comparative statics for the existence of the licensing equilibrium then shows that the incentive for licensing is strictly decreasing in the market entry probability of the own partner (ρ_i, say) and strictly increasing in the rival's market entry probability (ρ_j, say). The intuition for the influence of ρ_i is as follows: as long as firm i benefits from the market entry of the own Southern partner in the high tech market, it will always outsource regardless of ρ_j as the profits in the low-tech market are strictly higher with licensing. Hence, no licensing can only be better for i if the partner's market entry leads to lower joint profits in the high-tech market, so that the incentive to play an licensing equilibrium is strictly decreasing in ρ_i.

As to the impact of ρ_j, recall from section 3 that the benefit from entering the market is higher if the rival's Southern partner is in the market: if so, the profit increases from $\tau/9$ to $\tau/8$, whereas it increases from $\tau/4$ to $2\tau/9$ if the rival's partner is not in. And as $(\tau/8 - \tau/9) - (2\tau/9 - \tau/4) = \tau/24 > 0$, the result follows.

A promising extension of our analysis is to consider technology transfers in a dynamic set-up. The competitive effects of technology transfers may then be considered in a Vernon (1966)-style product cycle.[10] Licensing of a more mature good may then influence entry in the market for younger goods. Another possible extension concerns the role of intellectual property rights protection. As we have seen, firms may use technology transfers as a strategic instrument to counter technology transfers of their competitor; we can therefore imagine situations where firms do not employ existing instruments of protecting intellectual

[10]For a recent analysis of the product cycle model see (Antras 2005).

property rights for the same strategic reason.

6 Appendix

This appendix shows that licensing by only one firm does not maximize aggregate profits. First, compare the case of licensing by both firms with licensing by only one firm. Aggregate profits of both Northern firms are higher under licensing by both firms compared to licensing by only one firm, if

$$2\Pi_{SS} - \Pi_{NS} - \Pi_{SN} = \frac{\rho^2\tau}{12} - \frac{\rho\tau}{6} + \frac{c\,(2\bar{p} - c)}{2t} > 0.$$

Aggregate profits are higher under no licensing by both firms compared to licensing by only one firm, if

$$2\Pi_{NN} - \Pi_{NS} - \Pi_{SN} = \frac{\rho\tau}{6} - \frac{c\,(2\bar{p} - c)}{2t} > 0.$$

At least one of these inequalities is satisfied. Thus, asymmetric licensing does not maximize aggregate profits.

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