Internalization and licensing

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1 A model of licensing with technology diffusion

Our model consists of two periods, t and $t+1$. In period t, only the final-good firm knows how to operate the final-good technology, which turns one unit of components, m, into final goods which are sold to generate revenues, R.

As in previous models, the other firm (in this case, a potential licensee) can produce the components at a marginal cost that is lower than the final-good firm's marginal cost. This is the final-good firm's incentive to license its technology.

A final-good firm must choose between two ways to organize production.

1. **Integrate**. Both stages of production are done within the final-good firm.
2. **License**. Contract with an arm's-length firm (the licensee) to produce the components and the final good. In return, the final-good firm receives license payments from the licensee.

Notice the difference between licensing and the contracting problem from the our model of hold up. In the licensing firm structure, the final-good firm turns over its final-good technology to be used by the licensee. The licensee is in charge of all the production, and gets to keep whatever it earns after paying the license fee. The licensee is the *residual claimant* of the returns to production. This structure eliminates the supplier's incentive problem that is present in the hold-up model.

The danger with licensing, however, is that the licensee will learn about the final-good technology, and can imitate it in the second period. If the licensee copies the technology, it does so imperfectly, and the cost associated with operating the technology increases relative the cost when the licensee stays in the license agreement. When should the final-good firm license and when should it produce? What does the license agreement look like? We tackle these questions below.

To make our lives simple, we assume that prices do not change between the two periods.

1.1 Integration

If the final-good firm chooses to create the components in-house, it avoids problems with its technology diffusing to the licensee, but the final-good firm is not as efficient at producing components. The licensee can produce components at a cost of p_m per unit. Components produced by the final-good firm cost γp_m per unit, where $\gamma > 1$. The final-good firm pays a fixed cost f to keep its production technology running smoothly. If the final-good firm integrates, its profits are

$$\pi_F^I = (R - \gamma p_m - f) + \frac{(R - \gamma p_m - f)}{1+r}. \tag{1}$$

The first term in (1) is the profit in period t and the second term is the profit in period $t+1$ discounted by the interest rate ($r > 0$), so that the period t and period $t+1$ profits are comparable. [Profits in the future are "worth less" than profits today.]

1.2 Licensing

In this section we analyze the licensing firm structure. The licensee makes two license payments to the final-good firm, L_t and L_{t+1}. The final-good firm gives the licensee the production technology, but the final-good firm still pays f to keep the technology operating smoothly. This cost may represent, for example, technical support provided to the licensee. The final-good firm also pays a cost to transfer the technology, T. Ideas that are hard to transfer might entail a large T, while easy to transfer technologies would have a low T. The final-good firm's total profits when licensing are

$$\pi_F = (L_t - f - T) + \frac{(L_{t+1} - f - T)}{1 + r}. \tag{2}$$

The first term in (2) is the final-good firm's profit in the first period: the license fee minus the fixed cost and the transfer cost. The second term is the second period profit (the license fee minus the fixed cost and transfer cost) discounted by the interest rate $r > 0$, so that the period t and period $t + 1$ profits are comparable.

1.2.1 The license agreement

If the licensee (S to keep the notation consistent with the hold-up model) chooses to stay in the license agreement for both periods, its profits are

$$\pi_S = (R - p_m - L_t) + \frac{(R - p_m - L_{t+1})}{1 + r_S}. \tag{3}$$

The first term in (3) is the profit from producing in the first period minus the license cost and the second term is the profit from producing in the second period, minus the license cost, discounted by the interest rate. We allow the licensee to face a potentially different interest rate (r^S) than the final-good firm.

In period $t + 1$, after the licensee has learned how to use the production technology, it may want to break the contract and produce on its own, without paying the licensing fee. If it operates on its own, it must pay the fixed cost to keep the technology running smoothly. The licensee is not as good at this as the final-good firm, $f^S > f$. The profit of the licensee if it defects from the contract is (with D for "defect")

$$\pi_S^D = (R - p_m - L_t) + \frac{(R - p_m - f^S)}{1 + r_S}. \tag{4}$$

The final-good firm understands that the licensee may want to defect in period $t+1$. Any contract the final-good firm would agree to must provide an incentive for the licensee not to defect. This *incentive compatibility constraint* ensures that the value of defection is less than the value of staying in the license agreement,

$$\pi_S \geq \pi_S^D. \tag{5}$$

Comparing (3) and (4), it must be that

$$L_{t+1} \leq f^S, \tag{6}$$

which limits the size of the license fee in $t+1$. Any incentive-compatible license agreement must obey (6). We can rewrite the licensee's profits in (3) as

$$\pi_S = (R - p_m - L_t) + \frac{\left(R - p_m - f^S\right)}{1 + r_S}, \tag{7}$$

where we have substituted $L_{t+1} = f^S$, the smallest license payment that will keep the licensee from defecting.

What is the value of the period t license payment? There are many possible ways we could think about the final-good firm selling the rights to use its technology. We choose a simple one. Assume that there are many potential licensees. If the final-good firm has the potential licensees compete for the technology, they would eventually drive the value from obtaining the license to zero. The value cannot go below zero, or the licensee would not want to license the technology. This means that the L_t will be the value that makes (7) to zero,

$$\begin{aligned} 0 = \pi_S &= (R - p_m - L_t) + \frac{\left(R - p_m - f^S\right)}{1 + r_S} \\ L_t &= (R - p_m) + \frac{(R - p_m)}{1 + r_S} - \frac{f^S}{1 + r_S}. \end{aligned} \tag{8}$$

Notice that the license payments are front loaded. The first payment is much larger than the second. This is needed in order to make the contract self-enforcing. In the second period, the licensee knows how to operate the technology, so it pays a smaller license fee in order to make the licensee want to stay in the contract. In the first period, the licensee does not know how to use the technology, so the final-good firm can ask for a large license fee.

1.3 Integrate or license?

The final-good firm integrates when the profit from doing so is larger than the profit from licensing,

$$\begin{aligned} \pi_F^I &\geq \pi_F \\ R - \gamma p_m - f + \frac{R - \gamma p_m - f}{1 + r} &\geq L_t - f - T + \frac{f^S - f - T}{1 + r} \\ R - \gamma p_m - f + \frac{R - \gamma p_m - f}{1 + r} &\geq R - p_m + \frac{R - p_m}{1 + r_S} - \frac{f^S}{1 + r_S} - f - T + \frac{f^S - f - T}{1 + r}. \end{aligned} \tag{9}$$

Whenever (9) holds, the final-good firm will integrate.

1.4 Identical discount rates

If $r = r^S$, the two firms value future profits the same way. In this case, (9) simplifies to

$$T \geq p_m (\gamma - 1). \tag{10}$$

The left-hand side of (10) is the cost of technology transfer that the final-good firm pays to transfer the technology. The right-hand side is the cost of integrating — the final-good firm pays $\gamma - 1$ more than the licensee if it produces components.

Notice that, if it is free to transfer the technology ($T = 0$), then (10) is always false, and the final-good firm always licenses. Why is this so? We can compute the value of the license payments for the final-good firm as $V_F = L_t + L_{t+1}/(1+r)$. The two payments are

$$L_t = (R - p_m) + \frac{(R - p_m)}{1+r} - \frac{f^S}{1+r} \tag{11}$$

$$L_{t+1} = f^S, \tag{12}$$

so the value of the license contract is

$$V_F = (R - p_m) + \frac{(R - p_m)}{1+r}. \tag{13}$$

The payments to the final-good firm are equal to entire surplus generated by production. The final-good firm is able to extract all of the surplus from the license agreement, so the final-good firm will always want to license if the cost of licensing is zero.

Numerical example

Assume $R = 5$, $p_m = 1$, $f = 1.1$, $f^S = 1.2$, $T = 0.2$, $r = 0.03$, $r^S = 0.03$, $\gamma = 1.4$.

1. What are the license payments? Compute the net present value of license payments to the final-good firm, $V_F = L_t + L_{t+1}/(1+r)$.
2. Compute the license agreement surplus according to the final-good firm, $\sigma = R - p_m + (R - p_m)/(1+r)$.
3. Compute π_F^I and π_F. Should the final-good firm integrate or license?

Solutions:

1. The license payments are $L_t = 5 - 1 + (5 - 1 - 1.2)/1.03 = 6.72$ and $L_t = 1.2$. The present value of payments is $V_F = 6.72 + 1.2/1.03 = 7.88$.
2. The surplus is $\sigma = 5 - 1 + (5 - 1)/1.03 = 7.88$. Notice that the present value of the license payments is equal to the surplus.
3. Profit when integrated is $\pi_F^I = 5 - 1.4 - 1.1 + (5 - 1.4 - 1.1)/1.03 = 4.93$. Profit when licensing is $\pi_F = 6.72 - 1.1 - 0.2 + (1.2 - 1.1 - 0.2)/1.03 = 5.32$. The final-good firm should license the technology.

1.5 Heterogeneous discount rates

If $r < r^S$, the licensee values future profits less than the final-good firm values them. The stream of payments to the final-good firm in this case is

$$L_t = (R - p_m) + \frac{(R - p_m)}{1+r^S} - \frac{f^S}{1+r^S} \tag{14}$$

$$L_{t+1} = f^S. \tag{15}$$

The difference between (11) and (14) is the r^S. The value of this license agreement to the final-good firm is

$$V_F = (R - p_m) + \frac{(R - p_m)}{1+r^S} - \frac{f^S}{1+r^S} + \frac{f^S}{1+r}. \tag{16}$$

Notice that the f^S terms no longer cancel out. The licensee values f^S in the future less than the final-good firm values it.

How does this change the final-good firm's incentive to license? If we simplify (9) when $r < r^S$, we have

$$\left(\frac{R - p_m - f^S}{1 + r} - \frac{R - p_m - f^S}{1 + r^S} \right) + T \left(1 + \frac{1}{1 + r} \right) \geq p_m \left(\gamma - 1 \right) \left(1 + \frac{1}{1 + r} \right). \tag{17}$$

The left-hand side of (17) is the cost of licensing and the right-hand side is the benefit from licensing. Notice that if $r = r^S$, this condition is identical to (10). When $r < r^S$, the first term on the right-hand side of (17) is positive: The cost of licensing increases.

The first term on the right-hand side of (17) is the difference in the second period surplus as valued by each firm. The final-good firm, with the lower interest rate, values the future surplus more than the licensee, which faces a higher interest rate. The final-good firm, however, cannot ask for a payment from the licensee for more than the licensee values the future surplus. This means that the final-good firm cannot extract all of the value of production from the licensee. This makes licensing less attractive to the final-good firm.

From (17), we can see the effect of different forces on the final-good firm's desire to license.

- An increase in T is an increase in the cost of transferring the technology. The larger is T, the less likely the firm is to license.
- An increase in γ is an increase in the benefit of the licensee producing rather than the final-good firm. The larger is γ, the more likely the firm is to license.
- An increase in $r^S - r > 0$ is an increase in the value of the technology that the final-good firm cannot recover from the licensee. The larger is $r^S - r > 0$, the less likely the firm is to license.
- An increase in f^S is an increase in the difficulty for the licensee to copy the technology. This only matters when $r \neq r^S$. In this case, an increase in f^S makes the firm more likely to license the technology.

Numerical example II

Assume $R = 5$, $p_m = 1$, $f = 1.1$, $f^S = 1.2$, $T = 0.2$, $r = 0.03$, $r^S = 0.25$, $\gamma = 1.4$. The interest rate available to the licensee has increased to 0.25.

1. What are the license payments? Compute the net present value of license payments to the final-good firm, $V_F = L_t + L_{t+1}/(1+r)$.
2. Compute the license agreement surplus according to the final-good firm, $\sigma = R - p_m + (R - p_m)/(1+r)$.
3. Compute π_F^I and π_F. Should the final-good firm integrate or license?
4. Compare V_F to V_F from the last example. Why are they different?

Solutions:

1. The license payments are $L_t = 5 - 1 + (5 - 1 - 1.2)/1.25 = 6.2$ and $L_t = 1.2$. The present value of payments is $V_F = 6.2 + 1.2/1.03 = 7.4$.
2. The surplus is $\sigma = 5 - 1 + (5 - 1)/1.03 = 7.88$. The surplus has not changed from the previous example — it does not depend on r^S.
3. Profit when integrated is $\pi_F^I = 5 - 1.4 - 1.1 + (5 - 1.4 - 1.1)/1.03 = 4.93$. Profit when licensing is $\pi_F = 6.2 - 1.1 - 0.2 + (1.2 - 1.1 - 0.2)/1.03 = 4.80$. The final-good firm should integrate the technology. It cannot elicit a large enough payment from the licensee to make it worth licensing. Why can it not elicit a large enough payment? The licensee does not value the future profit from production as much as the final-good firm does.
4. The present value of the license payments in this case is 7.4, compared to 7.88 in the last example (which is also the value of the surplus to the final-good firm). The final-good cannot extract the 0.48 from the licensee any longer, and this is enough to make integrating a better option.

On your own, compute the three terms in (17) and compare them to your calculations above.