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Outsourcing and technology spillovers

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Abstract

This paper presents a model that helps explain incomplete outsourcing in the presence of spillovers. Outsourcing may require training of workers in the low wage economy. Such training yields spillover benefit to rival firms located in the low wage economy. The outsourcing firm must balance the marginal gain (cost saving) with the marginal cost (lowering rivals' cost).

Keywords: Outsourcing; Technology; Spillover

1. Introduction

One of the reasons for international outsourcing by firms located in advanced economies is that labor is cheaper in less developed countries. In many cases, a parent company sets up a subsidiary in a low wage economy, and asks it to produce upstream components, while it retains head office activities such as design, patent application and marketing. However, in some cases, a small fraction of upstream component production continues to be carried out at home, while the remaining fraction is outsourced abroad. Even companies that place a high value on integrated production, outsource some of their R&D activities, to take advantage of cheaper R&D labor in countries. We call such cases "incomplete outsourcing". This paper presents a model that helps explain the phenomenon of incomplete outsourcing.

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We include a feature of outsourcing that does not seem to have received sufficient attention in the literature. Outsourcing may require training of workers in the low wage economy so that the upstream components meet the quality specifications of the head office. We posit that such training yields external economies to rival firms located in the low wage economy.

Basically, we argue that when a firm outsources its production, it must balance the marginal gain (cost saving) of outsourcing an additional unit with the marginal cost of doing so (lowering rivals' cost). Thus a firm that contemplates outsourcing must take into account both cost-saving considerations and strategic considerations.

To keep our story simple, we construct a model of international duopoly with differentiated products. We show that under certain assumptions on parameter values, a firm may choose incomplete outsourcing. A surprising result is that an increase in the training cost of labor in the low wage economy will increase the extent of outsourcing, and decrease the employment level of the foreign rival.

We will abstract from considerations such as service links because these have been discussed elsewhere (see Feenstra, 1998; Ho & Hoon, 2003; Hoon & Ho, 2001; Jones & Kierzkowski, 1990, 2001; Long, Riezman, & Soubeyran, 2001).

2. The model

2.1. Notation and assumptions

There are two countries, home (H) and foreign (F), and two firms, 1 and 2. Country H is the high-wage economy, and country F is the low-wage economy. Firm 1 can produce good 1 in two locations: H and F. Firm 1 is said to outsource its production if a fraction of its output is produced in F. Firm 2 produces good 2 in country F. Good 1 and good 2 are imperfect substitutes. The inverse demand function for good i is:

$$P_i = P_i(Q_i, Q_j)$$

We assume that

$$\frac{\partial P_i}{\partial Q_i} < 0$$

$$\frac{\partial P_i}{\partial Q_j} > 0.$$

Both firms operate under constant returns to scale. In H, one unit of labor produces one unit of good 1 (training is not necessary). The wage rate H is w_H. In F, to produce good 1, firm 1 needs to train its workers. Let T denote the cost of training a worker, and w_F denote the wage rate in F. For firm 1, the marginal cost of good 1 in F is w_F+T. In what follows, we assume that the wage differential exceeds the training cost.

Assumption A1. The wage differential exceeds the training cost, i.e.

$$w_H - w_F > T.$$

It follows from Assumption A1 that, in the absence of strategic considerations, firm 1 would have an incentive to outsource all of its production to location *F*. Let Q_{1H} and Q_{1F} denote the outputs, L_{1H} and L_{1F} the numbers of employees, of firm 1 in country *H* and country *F*, respectively. Then

$$Q_{1F} = L_{1F}$$

$$Q_{1H} = L_{1H}$$

Let us turn to the production of good 2, which takes place only in country *F*. We assume that the productivity of labor in country *F* in the production of good 2 is 1+*s* where *s* captures the spillover effects of firm 1's training of its workers on firm 2's labor productivity. We assume that *s* is an increasing function of the number of workers trained by firm 1:

$$s = s(L_{1F})$$

where

$$s(0) = 0, s'\ (L_{1F}) > 0.$$

It follows that the output of firm 2 is dependent on both L_{1F} and on its employment level:

$$Q_2 = (1 + s(L_{1F}))L_2$$

It will be convenient to use the following notation

$$b(L_{1F}) = 1 + s(L_{1F}).$$

2.2. Optimization problem of firm 1

We now consider the optimization problem of firm 1. We assume that firm 1 takes L_2 as given. It chooses L_{1F} and L_{1H} to maximize its profit

$$\pi_1 = P_1(L_{1F} + L_{1H}, b(L_{1F})L_2)(L_{1F} + L_{1H}) - w_H L_{1H} - (w_H + T)L_{1H}$$

The first-order conditions are

$$\frac{\partial \pi_1}{\partial L_{1H}} = \frac{\partial P_1}{\partial Q_1}Q_1 + P_1 - w_H \leq 0, L_{1H} \geq 0, L_{1H}\frac{\partial \pi_1}{\partial L_{1H}} = 0$$

$$\frac{\partial \pi_1}{\partial L_{1F}} = \frac{\partial P_1}{\partial Q_1}Q_1 + P_1 + \frac{\partial P_1}{\partial Q_2}L_2 b'\ (L_{1F}) - w_F - T \leq 0, L_{1F} \geq 0, L_{1F}\frac{\partial \pi_1}{\partial L_{1F}} = 0$$

The following result follows immediately:

Proposition 1. *Under Assumption A1, if the two markets are independent, or if the two goods are complements, firm 1 will outsource all of its output.*

Proof. Suppose, on the contrary, that firm 1 does produce some of its output in the home country. Then L_{1H} is positive and

$$-\frac{\partial P_1}{\partial Q_1}Q_1 - P_1 + w_H = 0$$

$$\frac{\partial P_1}{\partial Q_1}Q_1 + P_1 + \frac{\partial P_1}{\partial Q_2}L_2 b'\ (L_{1F}) - w_F - T \leq 0$$

Adding these two conditions, we get

$$\frac{\partial P_1}{\partial Q_2}L_2 b'\ (L_{1F}) + w_H - w_F - T \leq 0$$

which implies $w_H - w_F - T \leq 0$.

This is in contradiction with Assumption A1. This completes the proof of Proposition 1. □

Corollary 1. *Under Assumption A1, firm 1 diversifies its employment (i.e., it produces at both locations) only if the level of employment of firm 2 is positive and the two goods are substitutes.*

Proof. Diversification of employment means that all the conditions in the proof of Proposition 1 hold with equality. Thus, in view of Assumption A1,

$$\frac{\partial P_1}{\partial Q_2}L_2 b'\ (L_{1F}) = w_H - w_F - T > 0$$

This is possible only if the level of employment of firm 2 is positive and the two goods are substitutes. □

Example 1. Let us specify that

$$P_1 = 1 - Q_1 - \delta Q_2$$

and w_F and w_H are both less than unity.

If $\delta \in (0,1)$ we say that goods 1 and 2 are imperfect substitutes. If $\delta < 0$, the two goods are said complements. If $\delta = 0$, the two markets are said to be independent. If $\delta = 1$, the two goods are said to be perfect substitutes.

If, in addition, the function $b(L_{1F})$ is linear, say $b'\ (L_{1F}) = \alpha > 0$, then firm 1's diversification occurs only if

$$L_2 = \frac{w_H - w_F - T}{\alpha\delta}.$$

2.3. Optimization problem of firm 2 under Cournot–Nash behavior

Under the "Cournot—Nash behavior" hypothesis, firm 2 takes the employment levels L_{1H} and L_{1F} as given. It chooses its own employment level to maximize its profit

$$\pi_2 = P_2(L_{1F} + L_{1H}, Q_2)Q_2 - w_F L_2$$

where

$$Q_2 = b(L_{1F})L_2$$

The first-order condition is

$$\frac{\partial \pi_2}{\partial L_2} = Q_2 \frac{\partial P_2}{\partial Q_2} \frac{\partial Q_2}{\partial L_2} Q_1 + P_2 b(L_{1F}) - w_F \leq 0, L_2 \geq 0, L_2 \frac{\partial_2}{\partial L_2} = 0$$

We assume that the second-order condition is satisfied. Then from the first-order condition we obtain firm 2's reaction function

$$L_2 = R_2(L_{1F}, L_{1H})$$

Example 1 (continued). Suppose the demand functions are linear.

$$P_1 = 1 - Q_1 - \delta Q_2$$

$$P_2 = 1 - Q_2 - \delta Q_1$$

Then the first-order condition is

$$-b(L_{1F})^2 L_2 + [1 - b(L_{1F}) - \delta L_{1F} - \delta_{1H}] b(L_{1F}) - w_F \leq 0$$

And the second-order condition at an interior maximum is

$$\frac{\partial^2 \pi_2}{\partial L_1^2} = -2b(L_{1F})^2 \leq 0.$$

The reaction function of firm 2 is

$$L_2 = R_2(L_{1F}, L_{1H}) = \frac{1 - \delta L_{1F} - \delta L_{1H} - w_H}{2(b(L_{1F}))^2}$$

Thus

$$\frac{\partial L_2}{\partial L_{1H}} = -\frac{\delta}{2(b(L_{1F}))^2} \leq 0$$

$$\frac{\partial L_2}{\partial L_{1F}} = -\frac{\delta}{2(b(L_{1F}))^2} - \frac{[1 - \delta L_{1F} - \delta L_{1H} - w_H] b'(L_{1F})}{(b(L_{1F}))^4} < 0.$$

The right-hand side of the preceding expression is negative for $\delta \geq 0$. Even in the case $\delta = 0$, an increase in L_{1F}, by decreasing the marginal value product of L_2 at any given employment level L_2, makes firm 2 reduce its labor demand.

Thus we have proved the following proposition:

Proposition 2. *Under the linear demand specification, if the two goods are substitutes (perfect or imperfect) or if the two markets are independent, an increase in firm 1's outsourcing will cause firm 2 to reduce its labor force.*

3. Interior Nash–Cournot equilibrium

In what follows, we assume that the two demand functions are linear, as specified in example 1, and both wage rates are smaller than the vertical intercept of the demand curve, which is unity. Our first task is to find conditions under which all the three employment levels L_{1F}, L_{1H} and L_2 are positive in a Nash equilibrium. Such equilibrium will be called an interior Nash–Cournot equilibrium.

At an interior Nash–Cournot equilibrium we have three conditions. First, the employment level of firm 2 is on its best reply curve:

$$L_2 = R_2(L_{1F}, L_{1H}) = \frac{1 - \delta L_{1F} - \delta L_{1H} - w_H}{2(b(L_{1F}))^2}$$

Second, the employment solution in the home country is not at a corner:

$$(L_{1F} + L_{1H}) - (1 - L_{1F} - L_{1h} - \delta b(L_{1F})L_2) + w_H = 0$$

Third, at the margin, the marginal gain from outsourcing (wage saving) is equal to the marginal cost of outsourcing (lowering rival's cost):

$$w_H - w_F - T = \delta L_2 b' \ (L_{1F})$$

To simplify, let us assume

Assumption A2. The function $b(L_{1F})$ is linear: $b(L_{1F})=1+\alpha L_{1F}$, where $\alpha>0$.

We then have at an interior equilibrium

$$w_H - w_F - T = \alpha\delta L_2.$$

Let us define the full wage differential by

$$\Delta \equiv w_H - w_F - T.$$

Then

$$L_2 = \frac{\Delta}{\alpha\delta}.$$

Thus we can state the following results:

Proposition 3. *Under Assumptions A1 and A2, for given values of α, δ and the full wage differential δ, an interior equilibrium can occur only at a single value of L_2:*

$$L_2 = \frac{\Delta}{\alpha\delta} \equiv J$$

Proposition 4. *Assume Assumptions A1 and A2, and parameter values that lie in an open set S that permits an interior equilibrium. Then an increase in δ (the degree of substitutability of the two goods) or in α (the spillover coefficient) or an increase in the training cost will result in a fall in the employment level of firm 2.*

Let us look at the open set S in more detail.

Substituting for L_2 into the first two conditions of an interior Nash–Cournot equilibrium, we get two equations:

$$J = \frac{1 - \delta L_{1F} - \delta L_{1H} - w_F}{2(1 + \alpha L_{1F})^2}$$

$$(L_{1F} + L_{1H}) - (1 - L_{1F} - L_{1h} - \delta(1 - \alpha L_{1F})J) + w_H = 0$$

The first equation yields

$$2J\left(1 + \alpha^2 L_{1F}^2 + 2\alpha L_{1F}\right) = 1 - \delta L_{1F} - \delta L_{1H} - w_H$$

The second equation yields

$$L_{1H} = \frac{1 - w_H - \delta J - (2 + \alpha\delta J)L_{1F}}{2}$$

Substituting for L_{1H} we get a quadratic equation in L_{1F}

$$A(L_{1F})^2 + BL_{1F} + C = 0$$

where

$$A \equiv 2J\alpha^2 > 0$$

$$B \equiv \frac{\left(8 - \delta^2\right)\alpha J}{2} > 0$$

$$C \equiv 2J - Z$$

$$Z \equiv (1 - w_F) - \frac{\delta}{2}(1 - w_H) > 0$$

Consider two cases: Case 1 ($C<0$) and Case 2 ($C>0$).

We note that C/A is the products of the roots, and $-B/A$ is the sum of the roots. We know that B is positive. Thus, if $C<0$, we have two real roots, of which one is negative and one is positive, which is the economically relevant root, since the quantity of labor cannot be negative. If $C>0$, then we either have two complex roots, which means there is no economically meaningful solution, or two real roots of the same sign (which is negative, because $-B/A$ is negative). Again this means there is no economically meaningful solution. Thus we focus only on Case 1. (There is also the razor edge case, $C=0$, in which case we have repeated roots, both of which are negative, which means there is no economically meaningful solution).

Case 1 occurs if and only if $2J<Z$. This holds when the training cost is sufficiently high and/or the spillover coefficient α is small. In this case, since $C<0$, the quadratic equation has one positive root and one negative root. We take the positive root:

$$L_{1F}^{*} = -\frac{\left(8-\delta^2\right)}{8\alpha} + \frac{1}{4\alpha}\left[\frac{\left(8-\delta^2\right)^2}{4} - 16 + \frac{8Z}{J}\right]^{1/2} > 0$$

Then

$$L_{1H}^{*} = \frac{1 - w_H - \delta J - (2 + \alpha\delta J)L_{1F}^{*}}{2}$$

Proposition 5. *Under Case 1, an increase in the training cost will result in an increase in outsourcing.*

Proof. An increase in T will lower J and hence raise L_{1F}^{*}. □

Remark. Proposition 5 is rather surprising. Clearly, this result can only be a local property, because if T is high enough, J will become negative, which violates our Assumption A1.

4. Concluding remarks

We have modeled the outsourcing decision of a firm facing a foreign rival that could benefit from the spillovers associated with the training of workers by the outsourcing firm. We showed that considerations of such spillovers may lead the outsourcing firm to retain some of the production at home despite the higher labor cost. Thus, even with linear technology, a firm may diversify its production.

The model could be extended in several directions. First, the workers trained by firm 1 may leave the firm to work for its rival, possibly after one period. Second, more rivals may enter in later periods, as the pool of skilled workers becomes bigger after successive periods of training by firm 1. In this case, firm 1 must calculate the effect of its training on the equilibrium wage rate of skilled workers in country F.

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