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Outsourcing and R&D

by

Sugata Marjit and Arijit Mukherjee

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Abstract

This paper considers the effect of outsourcing on R&D of the contracting firm. We show that outsourcing increases (decreases) R&D investment in a declining (booming) industry. If outsourcing reduces potential R&D investment, it may also make the consumers worse off. We show that outsourcing raises R&D effort in more competitive product markets. If outsourcing takes place in unskilled activities, it is likely to increase R&D if proportion of skilled employment is higher and skill wage is relatively high. If outsourcing positively affects the productivity of the skilled workers, it provides further disincentive for R&D.

Keywords: Outsourcing; R&D; Skilled and unskilled labors

JEL Classification: F12; L14; L22; D23

Outline

Non-Technical Summary

There have been concerns that large number of jobs will be lost in the developed countries due to off shoring of unskilled and semi-skilled activities and therefore, laws should be designed to regulate such contracts. However, critiques of this argument have shown that there are substantial benefits from outsourcing as well.

This paper considers the effect of outsourcing on R&D of the contracting firm. We show that outsourcing increases (decreases) R&D investment in a declining (booming) industry. If outsourcing reduces potential R&D investment, it may also make the consumers worse off. We show that outsourcing raises R&D effort in more competitive product markets. If outsourcing takes place in unskilled activities, it is likely to increase R&D if proportion of skilled employment is higher and skill wage is relatively high. If outsourcing positively affects the productivity of the skilled workers, it provides further disincentive for R&D.

1. Introduction

Outsourcing of productions from USA to countries such as India, Brazil and China, has emerged as a popular topic of discussion both in the academic circle and the media. There have been concerns that large number of jobs will be lost in the developed countries due to off shoring of unskilled and semi-skilled activities and therefore, laws should be designed to regulate such contracts. However, critiques of this argument have shown that there are substantial benefits from outsourcing as well. The recent loss of jobs in USA is primarily due to technological restructuring rather than outsourcing. An interesting write up in this context is by Drezner (2004).

Academic research on outsourcing is gradually growing in number. Papers by Grossman and Helpman (2002 and 2003), Buehler and Haucap (2003), Egger and Egger (2003), Shy and Stenbaka (2003), Rossini and Lambertini (2003) and Antràs and Helpman (2004) talk about contractual and strategic implications of outsourcing and show the advantage of international outsourcing over other organizational structures such as vertical integration and foreign direct investment. Feenstra and Hanson (1999) and Jones (2004) provide a trade theoretic angle to the problem. While Feenstra and Hanson (1999) estimates the impact of outsourcing on relative wage within USA, Jones (2004) compares immigration and outsourcing since both tend to affect local wage.[1]

The purpose of the present paper is to look beyond the issues raised in the wage and employment debate. We analyze the implications of outsourcing on R&D of a technology leader engaged in outsourcing, i.e., whether accessing cheap labor overseas is good or bad for further R&D effort of the contracting firm.[2] If such activities adversely affect future R&D, eventually consumers' surplus can be adversely affected. On the other hand, positive impact on R&D will definitely reinforce the arguments in favor of outsourcing. We use a Cournot oligopoly model with the outsourcing firm as the potential innovator. In a simple framework, many interesting results are derived. In general, outsourcing has offsetting effects on R&D and it is likely to improve R&D effort in declining industries. Further, outsourcing is likely to raise R&D effort in a more competitive market. In case the firm engaged in outsourcing is quite efficient, further R&D may be

[1] A special issue of the journal 'International Review of Economics and Finance' in 2005 (vol. 14; issue, 3) has been devoted to the recent contributions on outsourcing.

[2] There is a growing literature on the outsourcing of innovation that focuses on the trade-off between the transaction cost economies and the property rights (see, e.g., Ulset, 1996, Love and Roper, 2001 and Lai et al., 2003). However, unlike these works, we consider outsourcing of production and analyze the effect of this strategy on innovation.

negatively affected and consumers' surplus may eventually go down because without outsourcing R&D could have been higher.

We extend the basic model to incorporate both skilled and unskilled workers in the production process and allow outsourcing to take place only in unskilled activities. In this case outsourcing is likely to raise R&D expenditure if proportion of skilled employment is higher and skill wage is relatively high. If outsourcing affects productivity of skilled worker also, negative impact on R&D is further magnified, as it further reduces the cost of production of the outsourced firm. Since outsourcing is a recent phenomenon, it will take time before its impact on R&D is fully ascertained. One positive aspect of our paper is that it provides quite a few testable hypotheses one can work with in future.

This paper can also be related to Glass and Saggi (2001), where the effect of outsourcing on R&D investment has been examined in a product cycle model with patent race. In contrast, we consider a deterministic R&D model with a foreign technology leader and show that outsourcing can also reduce R&D investment and therefore, can also increase price of the product. Further, unlike them, we show the effects of skill differences on the relationship between outsourcing and R&D.[3]

The remainder of the paper is organized as follows. Section 2 builds up the basic model. Section 3 and 4 discuss the main results. Section 5 analyzes the case when outsourcing of relatively unskilled activities positively affects the productivity of the skilled labor. Section 6 concludes.

2. Model

Let us consider a country, called domestic country, with a firm, who wants to sell its product in the world market. Let us denote this firm as firm 1. We assume that there is other $(n-1)$ number of firms in the world market competing with firm 1. The inverse market demand function is given by

$$P = a - q\,, \tag{1}$$

where the notations have usual meanings.

Production requires workers and wage rate in the domestic country is w. We assume that firm 1 requires α workers to produce one unit of output. However, firm 1 does R&D to reduce labor content in its production, i.e., $\alpha = \alpha(R)$ with $\alpha' < 0$ and $\alpha'' < 0$, where R is the amount of R&D investment. Assume that R&D is costly and the cost of R&D is $c(R)$ with $c' > 0$ and $c'' > 0$.

[3] Recently, Mattoo et al. (2004) and Mukherjee (2004) show the implications of different types of foreign direct investment, viz., direct entry and acquisition, on R&D and welfare. One may refer to Spencer and Brander (1983) and Qiu and Tao (1998) for earlier works on trade and R&D.

We assume that marginal cost of each of the other $(n-1)$ firms is given by β, which can be greater or less than $w\alpha(R)$. Since, our focus is on the strategic decision of firm 1 only, we do not go into the details of the cost structure of the other $(n-1)$ firms. In other words, we are not going to be explicit about the formation of β.

We consider the following game. At stage 1, firm 1 chooses R&D investment. At stage 2, firms produce like Cournot oligopolists and profits are realized. Hence, we consider a situation where firm 1 becomes a technology leader in the world market. We solve the game through backward induction.

Given the R&D investment R, firm 1 chooses output to maximize the following expression:

$$\underset{q_1}{Max}(a-q-w\alpha(R))q_1. \tag{2}$$

Optimal output of firm 1 is

$$q_1^* = \frac{(a-nw\alpha(R)+(n-1)\beta)}{(n+1)} \tag{3}$$

and output of each of the other $(n-1)$ firms is

$$q_o^* = \frac{(a-2\beta+w\alpha(R))}{(n+1)} \tag{4}$$

Throughout our analysis, we assume that both q_1^* and q_o^* are positive, i.e., $\frac{a+w\alpha(R)}{2} > \beta > \frac{nw\alpha(R)-a}{(n-1)}$.

Optimal profit of firm 1 is

$$\pi_1^* = \frac{(a-nw\alpha(R)+(n-1)\beta)^2}{(n+1)^2} - c(R). \tag{5}$$

At stage 1, firm 1 maximizes expression (5) to determine the optimal amount of R&D investment. We find that the optimal R&D investment is given by

$$-\frac{2nw\alpha'(a-nw\alpha(R)+(n-1)\beta)}{(n+1)^2} = c'. \tag{6}$$

Assume that the second order condition for maximization is satisfied, i.e., $\Delta \equiv \frac{-2[(a-nw\alpha(R)+(n-1)\beta)nw\alpha''-(nw\alpha')^2]}{(n+1)^2} - c'' < 0$.

3. Outsourcing

So far we have assumed that firm 1 produces in the domestic country. Now we see the implications of outsourcing on our analysis. Assume that there is another country, called foreign country, where the wage rate is lower than the domestic country, which provides the incentive for outsourcing by firm 1 to the foreign country. We consider the following game. At stage 1, firm 1 does R&D. At stage 2, firm 1 decides on outsourcing. At stage 3, the firms compete as Cournot oligopolists. Since, there is no cost of outsourcing in our framework, it is clear from (3) and (5) that, given the R&D investment, outsourcing increases firm 1's output and the net profit at stage 2 compared to no outsourcing. Therefore, firm 1 will always outsource at stage 2.[4]

Proposition 1: *Outsourcing increases (decreases) firm 1's R&D investment if and only if* $a < (>) n(2w\alpha - \beta) + \beta$.

Proof: If we differentiate (6) with respect to w, we get

$$\Delta \frac{\partial R}{\partial w} - \frac{2n\alpha'(a - nw\alpha + (n-1)\beta)}{(n+1)^2} + \frac{2n^2 w\alpha\alpha'}{(n+1)^2} = 0$$

or $$\frac{\partial R}{\partial w} = \frac{2n\alpha'(a - 2nw\alpha + (n-1)\beta)}{\Delta(n+1)^2}.$$

Therefore,

$$\frac{\partial R}{\partial w} < (>) 0 \quad \text{if and only if} \quad a < (>) n(2w\alpha - \beta) + \beta. \tag{7}$$

Since, outsourcing occurs if the wage rate is lower in the foreign country than the domestic country, the result follows from (7). Q.E.D.

The intuition of this result is as follows. As the wage rate goes down, the marginal benefit from R&D goes down by $-\frac{2n\alpha'(a - nw\alpha + (n-1)\beta)}{(n+1)^2}$, for one unit drop in w. The coefficient of such a loss is positively related to a. Therefore, the lower is a, the higher is the chance that a lower w means a higher R. However, there is another effect. A lower w also means higher output by $\frac{n\alpha}{(n+1)^2}$. Therefore, marginal benefit increases by $-\frac{2nw\alpha'\alpha}{(n+1)^2}$. So, the lower is a, the higher is the chance that a decline in w increases R. Hence, the above result implies that outsourcing is

[4] Since the purpose of this paper is to show the implications of outsourcing rather than determining the condition for profitable outsourcing, we have assumed away the cost of outsourcing to make outsourcing always profitable compared to no outsourcing. One may refer to Grossman and Helpman (2003) to see how the cost of outsourcing can affect the investment strategy of a firm between foreign investment and outsourcing.

likely to increase R&D investment in declining industries where a is sufficiently low. In Appendix A, we show the result of Proposition 1 with a general demand function, which implies that our result does not depend on the specific demand function and therefore, it is quite general.

Now, let us see the effect of an increase in the number of firms on the R&D investment under outsourcing. The following proposition follows immediately from condition (7).

Proposition 2: *(i) As the total number of firm increases, it increases the possibility of higher R&D investment under outsourcing.*
(ii) Outsourcing is likely to reduce R&D investment if the non-innovating firms are relatively cost efficient (i.e., having relatively low β) and the innovating firm's initial technology is sufficiently superior.

The above proposition provides a testable hypothesis. It implies that outsourcing by a firm is more likely to increase (reduce) its R&D investment if the industry is more (less) competitive. Typically more competition reduces the market share of the innovating firm and hurts R&D. However, outsourcing helps the firm to reduce its production cost for a given technology and the lower cost of production helps to offset the effects of competition. Hence, as w goes down, the chances are high that R will increase provided n is large relative to a.

The intuition for Proposition 2 is simple. If the market is highly competitive (i.e., higher values of n), the market share of firm 1 is negligible. In this situation, a slight wage reduction does not lower firm 1's marginal benefit from R&D significantly, for a given level of output. But, a wage reduction increases firm 1's output and creates a positive impact on R&D investment, which, in turn, encourages it to do more R&D. On the contrary, if the market is not very competitive, the market share of firm 1 is significant. In this situation, given firm 1's market share, a slight wage reduction increases profit of firm 1 significantly and reduces its incentive for R&D. But, lower wage rate increases firm 1's market share and output, and encourages firm 1 to do more R&D. However, since firm 1's initial market share is sufficiently large, a further wage reduction does not affect its market share significantly, and therefore, does not increase its R&D significantly for this effect. Therefore, the effect of initial higher market share of firm 1 dominates the effect of a further increase of the market share due to wage reduction and on the balance, reduces firm 1's R&D investment.

If the non-innovating firms are relatively cost efficient, it assigns relatively low market share to the innovating firm. So, the above argument implies that, in this situation, outsourcing is

likely to increase R&D investment. But, if the innovating firm's initial technology is sufficiently superior, it captures sufficiently higher market share. A slight reduction in the wage rate does not help to further increase the market share of the innovating firm but it reduces its marginal benefit from R&D. So, in this situation, a further cost reduction through outsourcing reduces R&D investment.

Now, we see how outsourcing affects the consumers. For a given R&D investment and the wage rate, total output is $q^* \equiv q_1^* + (n-1)q_o^* = \frac{(na - w\alpha(R) - (n-1)\beta)}{(n+1)}$. Hence, it is clear that, total output and consumer surplus (which is $\frac{q^{*2}}{2}$) increase if outsourcing reduces firm 1's marginal cost of production, which is $w\alpha(R)$.

Proposition 3: *Outsourcing reduces consumer surplus if α is sufficiently low.*

Proof: If α is sufficiently low (e.g., $\alpha \to 0$), condition (7) shows that $\frac{\partial R}{\partial w} > 0$. Further, we find that $\frac{\partial(w\alpha(R))}{\partial w} = \alpha(R) + w\alpha' \frac{\partial R}{\partial w}$, which is negative if and only if

$$\alpha(n+1)^2 < \frac{-2nw\alpha'^2(a - n(2w\alpha - \beta) - \beta)}{\Delta} \tag{8}$$

and condition (8) holds for sufficiently low values of α. Q.E.D.

If the initial technology of the innovating firm is highly efficient, a reduction in the wage rate due to outsourcing does not increase its output significantly, whereas the lower wage rate induces the firm to lower its R&D investment. As a result, the marginal cost of the innovating firm tends to be higher relative to a situation without outsourcing, which reduces total output and consumer surplus.

4. The effects of skill differential

So far we have assumed that the workers used by firm 1 are symmetric. However, often firms use different types of workers (e.g., skilled and unskilled) for their productions. It is also found that firms outsource the part of their productions carried out by the unskilled workers. While the jobs of

the unskilled workers do not require specialized knowledge, the jobs carried out by the skilled workers require specialized knowledge. So, the firms outsource their productions to get the advantage of a lower wage rate of the unskilled workers, while they continue to use skilled workers in the domestic country. The purpose of this section is to see how this skill differential affects our above analysis.

Let us assume that one unit of output of firm 1 requires θ fraction of skilled workers and $(1-\theta)$ fraction of unskilled workers. We assume that the wage rate of the skilled and the unskilled workers in the home country of firm 1 are respectively w_s and w. So, firm 1's marginal cost of production in the home country is $\bar{w} \equiv (\theta w_s + (1-\theta)w)$.

Therefore, optimal R&D investment of firm 1 is now given by

$$-\frac{2n\bar{w}\alpha'(a - n\bar{w}\alpha(R) + (n-1)\beta)}{(n+1)^2} = c'. \tag{8}$$

Now, consider the effect of outsourcing on R&D investment of firm 1. Since, firm 1 outsource part of the production carried out by the unskilled workers, the effect of outsourcing on R&D investment will be captured by the term $\frac{\partial R}{\partial w}$.

Proposition 4: (i) *Outsourcing increases (decreases) firm 1's R&D investment if and only if* $a < (>) n(2\bar{w}\alpha - \beta) + \beta$.

(ii) As the total number of firm increases, it increases the possibility of higher R&D investment under outsourcing.

(iii) Outsourcing is likely to reduce R&D investment if the non-innovating firms are relatively more cost efficient (i.e., having relatively lower β*) and the innovating firm's initial technology is sufficiently superior.*

Proof: (i) Differentiating (8) with respect to w, we get

$$\frac{\partial R}{\partial w} < (>) 0 \qquad \text{if and only if} \quad a < (>) n(2\bar{w}\alpha - \beta) + \beta. \tag{9}$$

Since, outsourcing occurs if the wage rate is lower in the foreign country than the home country, the result follows from (9).

(ii) It follows directly from condition (9).

(iii) It also follows directly from (9). Q.E.D.

The above proposition shows that the qualitative results of Propositions 1 and 2 remain even if we consider skill differences between the workers. However, now the critical condition that determines the effect of outsourcing on R&D depends on the average wage rate, which is the weighted average of the skilled and unskilled wage rates. Hence, it is interesting to see how the intensity of the skilled and unskilled sectors affects the R&D investments due to outsourcing.

Proposition 5: *Outsourcing is likely to increase R&D investment for higher* θ*, higher* w_s *and higher* w.

Proof: The result follows directly from condition (9). Q.E.D.

Therefore, skill differential provides further effect on the relationship between outsourcing and R&D investment and shows that outsourcing is likely to increase R&D investment in the highly skilled sectors, where θ and w_s are high, and provides a testable hypothesis.

5. Outsourcing affecting productivity of the skilled workers

In the above analysis we have assumed that outsourcing only reduces wage rate of the unskilled workers. However, outsourcing may also make the skilled workers more productive apart from reducing the wage rate of the unskilled workers.

For example, think of the time difference between USA and India. In India, people work at a time when in the USA people take rest. Now, think of the IT sector and outsourcing of low-skilled routine jobs, which need further processing by skilled workers, by an USA firm to India. At the end of a working day, the USA firm can send jobs to its Indian counterpart by e-mail and get the reply before the next working day. Thus, it increases productivity of the USA employees by increasing its effective time of work.

If there was no time difference between USA and India, the skilled workers in the USA had to wait for the reply from the Indian workers. But, time difference between USA and India had eliminated this waiting time. So, such a positive effect of outsourcing will make higher R&D less likely under outsourcing, since now outsourcing further reduces the cost of production of the outsourced firm that further discourages costly R&D of this firm. To avoid repetition of our calculations, we skip the mathematical details of this section in the text and relegate it to Appendix B.

Proposition 6: *Outsourcing is less likely to increase R&D when it increases productivity of the skilled workers compared to the situation where outsourcing does not affect their productivity.*

It is worth mentioning that, in the above example, the USA firm could increase its total time of production by using multiple shifts of production. However, in that case, it had to pay higher wage rate to its employees in the USA compared to India. So, outsourcing helps the USA firm to increase productivity of its skilled labors at a lower wage rate. Since the effect of time difference can be utilized in the industries with no (or lower) transportation costs, the above result implies that outsourcing is more likely to increase R&D in the service sectors than the manufacturing sectors, which provides another testable hypothesis of our result.

6. Conclusion

This paper shows the implications of outsourcing on R&D effort of the contracting firm. We highlight the offsetting effect of accessing cheaper inputs on the incentives for R&D. In particular, we show that outsourcing is likely to increase R&D in the declining industries and more competition should enforce the pro-R&D impact of outsourcing. Further, intense competition reduces the negative impact of outsourcing on R&D and therefore, outsourcing increases R&D investment in a more competitive product market. We also show that in case R&D incentives are adversely affected, outsourcing, even if being a cost-reducing device, will eventually reduce consumers' surplus. Implications with both skilled and unskilled workers are also explored, and it is shown that positive impact on R&D will be strengthened with larger share of skilled workers in cost of production.

Concerns for and against the idea of outsourcing mainly take the form of targeting wage and employment scenario in labor market. We think that one needs to go beyond such a discourse and focus on relatively long term issues involving R&D and technology up gradation. This is a value added of this paper. Also we do generate many testable hypotheses involving market structure, outsourcing and R&D. We plan to undertake some of the empirical exercises in future.

Appendix A

Proposition 1 with general demand function: Suppose the inverse market demand function is $p = f(q+Q)$ with $f' < 0$, where q is the output of the outsourced firm (firm 1) and Q is the total output of the rest of the firms. Assume that q^* and Q^* are respectively the optimal output of firm 1 and total optimal output of the rest of the firms.

Therefore, at the R&D stage, net profit function of firm 1 is

$$[f(q^* + Q^*) - w\alpha(R)]q^* - c(R). \tag{A.1}$$

Hence, using the envelope theorem, we find that the optimal R&D investment of firm 1 satisfies the following condition:

$$q^*[f'\frac{\partial Q^*}{\partial R} - w\alpha'] - c' = 0. \tag{A.2}$$

Differentiating (A.2) with respect to w, we find that

$$\frac{\partial Z}{\partial R}\frac{\partial R}{\partial w} + [f'\frac{\partial Q^*}{\partial R} - w\alpha']\frac{\partial q^*}{\partial w} + \frac{\partial[f'\frac{\partial Q^*}{\partial R} - w\alpha']}{\partial w}q^* = 0 \tag{A.3}$$

It follows from (A.3) that if $q^* \to 0$ (which may be due to the competition effect as well as declining industry effect), the third term in (A.3) tends to 0. Therefore, in this situation, $\frac{\partial R}{\partial w}$ must be negative because $[f'\frac{\partial Q^*}{\partial R} - w\alpha'] > 0$ (since R&D investment of firm 1 makes it cost efficient and reduces outputs of other firms), $\frac{\partial q^*}{\partial w} < 0$ (since own cost reduction increases output of firm 1) and $\frac{\partial Z}{\partial R} < 0$ (due to the second order condition of profit maximization with respect to the R&D investment). But, when q^* is not very small and $\frac{\partial[f'\frac{\partial Q^*}{\partial R} - w\alpha']}{\partial w} > 0$, (A.3) can hold with a positive $\frac{\partial R}{\partial w}$. Q.E.D.

Appendix B

The mathematical details for section 5: Here we consider the situation where outsourcing of unskilled works also increases productivity of skilled workers due to the existence of time difference between regions. In other words, we may think outsourcing is reducing the effective cost of skilled workers. We modify the analysis of section 4 to write the marginal cost of production as

$$\overline{\overline{w}} \equiv (\theta w_s(t) + (1-\theta)w) \tag{B.1}$$

where t is a shift parameter. When w is reduced via outsourcing, it increases t, which lowers w_s. So, if there is outsourcing, it reduces $\overline{\overline{w}}$ due to its direct effect of lower w and an indirect effect of lower w_s. In this situation, optimal R&D investment of firm 1 is

$$-\frac{2n\overline{\overline{w}}\alpha'(a-n\overline{\overline{w}}\alpha(R)+(n-1)\beta)}{(n+1)^2} = c'. \tag{B.2}$$

Differentiating (B.2) with respect to w, we get

$$\frac{\partial R}{\partial w} < (>)0 \qquad \text{if and only if} \quad a < (>)n(2\overline{\overline{w}}\alpha - \beta) + \beta. \tag{B.3}$$

So, if there is no outsourcing, i.e., w is higher, it reduces R&D when $a < n(2\overline{\overline{w}}\alpha - \beta) + \beta$, which is a stricter condition than the condition shown in Proposition 4(i), since $\overline{\overline{w}} < \overline{w}$ due to $t > 0$. So, it implies that if outsourcing increases productivity of the skilled workers, it is less likely to increase R&D of firm 1 compared to the situation where outsourcing does not affect productivity of the skilled workers.

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