Economics Bulletin

Volume 30, Issue 4

Downstream R&D, raising rival's costs, and input-price contracts: a comment on the role of spillovers

Vasileios Zikos
University of Surrey, Department of Economics and University of the Thai Chamber of Commerce

Dusanee Kesavayuth
University of Chicago-UTCC Research Center, University of the Thai Chamber of Commerce

Abstract

We reconsider Banerjee and Lin [International Journal of Industrial Organization, 2003] by investigating the role of spillovers (or informational flows) for the profitability of input-price contracts in a vertically related industry. We show that spillovers influence the relative magnitude of the main forces operating in the model, which can either reinforce or alter some of the predictions.

Citation: Vasileios Zikos and Dusanee Kesavayuth, (2010) "Downstream R&D, raising rival's costs, and input-price contracts: a comment on the role of spillovers", *Economics Bulletin*, Vol. 30 no.4 pp. 3018-3025.
Submitted: Aug 15 2010. **Published:** November 13, 2010.

1 Introduction

Technological activities are important determinants of the firms' competitiveness. The ability to deliver innovations is becoming increasingly important in a rapidly evolving business environment and, in many instances, proves key to survival in the market place. A large number of Research and Development (R&D) projects are conducted in vertically related industries. That is, in industries consisting of both upstream and downstream firms. One can think of the upstream and the downstream firms as being input suppliers and final good manufacturers, respectively.[1]

Within this supplier-customer context, firms can implement different input-price contracts. Banerjee and Lin (2003) have proposed three different types of such contracts: a floating-price contract, a fixed-price contract, and an 'intermediate' type of arrangement, a reference-price contract. The main difference of these contract types is the timing in the selection of input prices and R&D investments. In particular, a floating price contract requires that first the downstream firms carry out their R&D investments, then the input supplier sets the input price, and finally the downstream firms compete in quantities. Because the input price is chosen after firms do their R&D, the input supplier can adjust the input price in order to extract rent from the research activity. This opportunistic behaviour on the part of the input supplier, which tends to discourage R&D, can easily be overcome if the upstream and downstream firms sign a fixed input-price contract. According to this contract type, the input supplier commits (credibly) not to raise the input price after investment is sunk. This in turn promotes R&D and thereby increases the purchase of the input from the supplier. Also, Banerjee and Lin (2003) contrast these two contract types (floating-price contract and fixed-price contract) with a reference-price contract, under which the R&D and input price decisions are taken simultaneously.

The analysis of Banerjee and Lin (2003) yields interesting insights into the role of contract types for R&D activity and their desirability from the viewpoint of the upstream as well as the downstream firms. However, the analysis rests on the assumption of zero spillovers (or informational flows). This assumption is rather restrictive particularly because nowadays the rapid change of technological progress makes it more difficult for firms to protect an invention by patenting it (Narula and Hagedoorn, 1999). In addition to this, knowledge can be disclosed to rival firms

[1] For instance, the computer industry fits well with description. In particular, the upstream tier of the industry consists of suppliers of operating systems, such as Intel and Microsoft, and suppliers of micro chips, such as Intel and Motorola. These upstream firms supply their inputs to personal computer manufacturers, such as Toshiba, IBM, Hewlett Packard and Sony, among others.

in other ways: industrial espionage, workers switching jobs and collaborative R&D agreements.[2] Indeed, considering the more plausible case of positive spillovers, we investigate the desirability of the different contract types. We show that spillovers influence the relative magnitude of the main forces operating in the model, which can either reinforce or alter some of the predictions.

2 The model

We modify the model of Banerjee and Lin (2003) by allowing for spillovers resulting from the R&D activity. The industry consists one upstream and two downstream firms, denoted respectively by U and D_i, $i = 1, 2$.[3] The upstream firm supplies a key input to the downstream firms at a wholesale price w. The downstream firms in turn transform the input into the final product. There is one-to-one relation between input and retail output. The downstream firms face a linear (inverse) demand for their product $p(Q) = a - Q$, with $Q = q_1 + q_2$ and $a > 0$. In addition, the downstream firms carry out cost-reducing R&D investments x_i at a cost x_i^2, implying a marginal production cost $\bar{c} + w - x_i - \beta x_j$, where $\beta \in [0, 1]$ captures the degree of spillovers, and $\bar{c}$ is the initial unit production cost with $a > \bar{c}$ (see d' Aspremont and Jacquemin, 1988).

The timing in the model is as follows. Under a floating-price contract, the downstream firms choose simultaneously their R&D investments, then the input supplier sets the price of the input, and finally downstream firms compete in quantities. Under a fixed-price contract, the timing for the first two stages is reversed, that is, the decision of the input supplier precedes the R&D decisions of the firms. Finally, under a reference-price contract, the input supplier and downstream firms make their decisions simultaneously at the initial stage of the game, and then the downstream firms compete in quantities. The games are solved by backward induction.

We proceed to obtain the subgame-perfect Nash equilibrium of the floating-price contract. The profit function of a downstream firm D_i is given by:

$$\pi_{D_i} = (a - q_i - q_j)q_i - (\bar{c} + w - x_i - \beta x_j)q_i - x_i^2, \quad i \neq j, \ i, j \in \{1, 2\}. \qquad (1)$$

Maximising profits with respect to q_i gives rise to the first order condition (foc) $A - w - 2q_i - q_j + x_i + \beta x_j = 0$, where $A \equiv a - \bar{c}$ is a measure of the market

[2] In the context of joint research agreements, firms collaborate in R&D but still remain competitors in the product market.

[3] We focus on a duopoly downstream as the number of firms is not important for the comparisons across contract types.

size.[4] The solution to the focs is the equilibrium of this stage game, $q_i = \frac{1}{3}(A - w + (2-\beta)x_i + (2\beta - 1)x_j)$. In the second stage, the input supplier chooses w to maximise its profit wQ, where $Q = \frac{1}{3}(2(A-w) + (1+\beta)(x_i + x_j))$. The resulting foc is $2A - 4w + (1+\beta)(x_i + x_j) = 0$.[5] The solution to the foc is the equilibrium of this stage game, $w(x_i, x_j) = \frac{1}{4}(2A + (1+\beta)(x_i + x_j))$. Using this expression, we can readily identify the effect of a unit increase in the R&D on D_i's marginal cost:

$$\frac{\partial MC_{D_i}}{\partial x_i} = \underbrace{-\frac{3}{4} + \frac{\beta}{4}}_{\text{cost reduction}} \tag{2}$$

$$\frac{\partial MC_{D_i}}{\partial x_j} = \underbrace{\frac{1}{4} - \frac{3\beta}{4}}_{\text{raising rivals' cost}} \quad , \quad i \neq j. \tag{3}$$

Intuitively, a marginal increase in D_i's R&D reduces own costs. Ceteris paribus, this leads to an increase in the demand for D_i's output, which in turn increases the demand for input. As a result, the input supplier will charge a higher input price, acting in an opportunistic manner (Banerjee and Lin, 2003). It is important to note that even though a higher input price moderates some of D_i's benefits from R&D (a negative incentive effect), it also translates into higher input costs for the rival downstream firm (a positive incentive effect). The latter effect, the so-called raising rival's cost effect, implies a strategic motive for D_i to carry out R&D. Furthermore, when β increases, the results of the R&D will spill-over to the rival firm so D_i will achieve a smaller overall cost reduction (see eq. (2)). The same is also true regarding the magnitude of the raising rival's cost effect, as eq. (3) indicates.

In the first stage of the game, the profit function of D_i is given by $\pi_{D_i}(x_i, x_j) = (q_i)^2 - x_i^2$. Maximising this with respect to x_i and imposing symmetry $x_i = x_j$, gives rise to the focs $5(1+\beta)(19-5\beta)x_i - (7-5\beta)(2A - (5-7\beta)x_j) = 0$. Solving the system of the focs yields the equilibrium of this stage game, $x_i^{FL} = \frac{(7-5\beta)A}{65-\beta(2-5\beta)}$, where the superscript FL denotes a floating-price contract.[6] Then one can easily obtain the rest of the equilibrium outcomes: $q_i^{FL} = \frac{12A}{65-\beta(2-5\beta)}$; $w^{FL} = \frac{36A}{65-\beta(2-5\beta)}$; $\pi_U^{FL} = \frac{864A^2}{(65-\beta(2-5\beta))^2}$ and $\pi_{D_i}^{FL} = \frac{5(1+\beta)(19-5\beta)A^2}{(65-\beta(2-5\beta))^2}$. This completes the analysis of the floating-price scheme. The solution procedure for the the fixed-price contract and the reference-price contract is the same as above so the equilibrium outcomes are relegated to the Appendix A.

[4] The second order condition (soc) is given by $-2 < 0$, so the foc is necessary and sufficient for an (interior) optimum.

[5] The soc of this maximisation problem is given by $-4 < 0$.

[6] For $\beta < (>)0.71$, the R&D competition game is played in strategic substitutes (complements). That is, $\partial^2\pi_i/\partial x_i \partial x_j = (7-5\beta)(-5+7\beta)/72 < (>)0$ if and only if $\beta < (>)\bar{\beta}$, where $\bar{\beta} \simeq 0.71$.

3 Comparison

A floating-price contract implies that the input supplier increases the input price after the downstream firms have conducted their cost-reducing investments. The higher input price reduces the marginal returns to R&D and thereby tends to discourage R&D. One way of overcoming the opportunistic behaviour of the input supplier implied by a floating-price contract is for both parties – upstream and downstream – to sign a fixed-price contract. Under a fixed price contract the input supplier commits not to raise the input price after investment is sunk. Consequently, the downstream firms will carry out more R&D while the supplier will make greater wholesale profit by selling more input.

Proposition 1 *The profit of the input supplier is ranked as* $\pi_U^{FI} > \pi_U^R > \pi_U^{FL}$ *for all* β.

Proposition 1 confirms that the assumption of zero spillovers in Banerjee and Lin (2003) does not alter the profit comparisons for the supplier across input-price contracts.

The next Proposition contains the ranking of the downstream firms' profit.

Proposition 2 *(i) A fixed-price contract secures the highest profit for the downstream firms,* $\pi_{D_i}^{FI} > \pi_{D_i}^{FL}$, $\pi_{D_i}^{FI} > \pi_{D_i}^{R}$ *for all* β.

(ii) There exists a threshold value $\tilde{\beta}$ *such that* $\pi_{D_i}^{FL} \leq \pi_{D_i}^{R}$ *if and only if* $\beta \geq \tilde{\beta}$, *and* $\pi_{D_i}^{FL} > \pi_{D_i}^{R}$ *otherwise.*

The main driving force behind part (i) is that a fixed-price contract promotes downstream R&D, which translates into higher output and profit. One might wonder how the presence of spillovers in our setting affects this result, which coincides with Banerjee and Lin (2003). An understanding of the influence that spillovers have on the marginal returns to R&D and, as a consequence, on the equilibrium profit, requires us to analyse how spillovers affect the size of the two main forces determining the desirability of a floating-price contract, namely, the cost reduction and the raising rival's cost effect. As can be seen from eq. (2) and (3), spillovers tend to moderate *both* effects. In particular, the size of cost reduction is reduced by the term $\frac{\beta}{4}$, whereas the raising rival's cost effect becomes less important according to the term $\frac{3\beta}{4}$. The prospects of the R&D incentives under a floating-price contract thus depend on the magnitude of these two terms. Clearly, the latter term is greater than the former, which implies that it is *less likely* that a floating-price contract will make the downstream firms better off in the presence of spillovers. A finding suggesting that the (implicit) assumption of perfect patent protection by Banerjee and Lin (2003) is 'innocuous' concerning the relationship between floating-price contracts and fixed-price contracts in the present setting. This, however, does not hold true regarding the relationship between floating-price contracts and reference-price contracts, as part (ii) of Proposition 2 indicates.

In particular, part (ii) reveals that when spillovers β are small enough, a floating-price contract secures greater profit for the downstream firms; otherwise, a reference-price contract leads to greater profit. This result reflects the aforementioned raising rival's cost effect of a floating-price contract. Indeed, when β is relatively small, an innovating firm can increase its rival's costs. In fact, it can do so without hurting itself as much due to increases of the input price, which are induced via spillovers. This in turn makes a floating-price scheme desirable.

Combining the results in Propositions 1 and 2, the following Corollary is immediate:

Corollary 1 *The interests of the input supplier and the downstream firms over the choice of input-price contract can fully be aligned if and only if* $\beta > \tilde{\beta}$.

Corollary 1 implies that independently of the type of input-price contract employed, both the input supplier and the downstream firms in the pursuit of their private interests can achieve an outcome that is 'collectively' beneficial. Particularly this is the case in the present setting when the degree of spillovers is sufficiently large.

Appendix A.

A.1 Fixed-price contract

Equilibrium outcomes are as follows:

$$w^{FI} = \frac{A}{2};\ x_i^{FI} = \frac{(2-\beta)A}{2(7-\beta(1-\beta))};\ q_i^{FI} = \frac{3A}{2(7-\beta(1-\beta))};$$
$$\pi_{D_i}^{FI} = \frac{(1+\beta)(5-\beta)A^2}{4(7-\beta(1-\beta))^2};\ \pi_U^{FI} = \frac{3A^2}{2(7-\beta(1-\beta))}. \tag{4}$$

A.2 Reference-price contract

Equilibrium outcomes are readily shown to be the following:

$$w^{R} = \frac{9A}{16-\beta(1-\beta)};\ x_i^{R} = \frac{(2-\beta)A}{16-\beta(1-\beta)};\ q_i^{R} = \frac{3A}{16-\beta(1-\beta)};$$
$$\pi_{D_i}^{R} = \frac{(1+\beta)(5-\beta)A^2}{(16-\beta(1-\beta))^2};\ \pi_U^{R} = \frac{54A^2}{(16-\beta(1-\beta))^2}. \tag{5}$$

Appendix B.

Proof of Proposition 1. We have the following comparisons:

$$\pi_U^{FI} - \pi_U^{R} = \frac{3(2+\beta-\beta^2)^2A^2}{2(7-\beta(1-\beta))(16-\beta(1-\beta))^2} > 0$$

$$\pi_U^{R} - \pi_U^{FL} = \frac{162(1+\beta)^2(43-2\beta+3\beta^2)A^2}{(16-\beta(1-\beta))^2(65-\beta(2-5\beta))^2} > 0.$$

It follows that $\pi_U^{FI} > \pi_U^{FL}$. Q.E.D.

Proof of Proposition 2. First we prove part (i). We have that:

$$\pi_{D_i}^{FI} - \pi_{D_i}^{FL} = \frac{3(835+2400\beta+375\beta^2-688\beta^3+357\beta^4-120\beta^5+25\beta^6)A^2}{4(7-\beta(1-\beta))^2(65-\beta(2-5\beta))^2} > 0.$$

Similarly, we establish the sign of the following difference:

$$\pi_{D_i}^{FI} - \pi_{D_i}^{R} = \frac{3(1+\beta)^2(100-80\beta+27\beta^2-8\beta^3+\beta^4)A^2}{4(7-\beta(1-\beta))^2(16-\beta(1-\beta))^2} > 0.$$

This completes part (i) of the proof.

Next we proceed to part (ii). Taking the difference $\pi_{D_i}^{R} - \pi_{D_i}^{FL}$ gives us:

$$\frac{9GA^2}{(16-\beta(1-\beta))^2(65-\beta(2-5\beta))^2},$$

where $G = -355 + 80\beta + 390\beta^2 - 16\beta^3 + 29\beta^4$. The sign of this difference depends on G. Note that $G = -355$ if $\beta = 0$ and $G = 128$ if $\beta = 1$. Further, $dG/d\beta = 80 + 780\beta - 48\beta^2 + 116\beta^3 > 0$. Hence, there exists a critical value of the spillover parameter defined as $\tilde{\beta} = \{\beta \mid G = 0\}$. Straightforward calculation yields $\tilde{\beta} \simeq 0.85$. Indeed, $\pi^R_{D_i} > \pi^{FL}_{D_i}$ if and only if $\beta > \tilde{\beta}$. Q.E.D.

References

[1] d' Aspremont, C. and Jacquemin, A. (1988) "Cooperative and Noncooperative R&D in Duopoly with Spillovers," *American Economic Review,* 78, 1133- 37.

[2] Banerjee, S. and Lin, P. (2003) "Downstream R&D, raising rivals' costs, and input price contracts," *International Journal of Industrial Organization,* 21 (1): 79-96.

[3] Narula, R. and Hagedoorn, J. (1999) "Innovating through strategic alliances: moving towards international partnerships and contractual agreements," *Technovation*, 19, 283-294.