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# VERTICAL INTEGRATION AND TECHNOLOGICAL SPILLOVERS

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## INTRODUCTION

This paper examines the relationships between vertical externalities, generated by vertical decentralisation in imperfect intermediate markets of technology, and horizontal externalities arising from R&D spillovers among downstream users. Literature is rich in examples which show the potential failures of the technology markets. Several authors have pointed out that encouragement of innovators' control over the final product that embodies new knowledge can solve the appropriability problem. «...Tolerating some degree of monopolisation in the innovation producing sector is an attracting way of internalising at least some of the externalities associated with R&D.» (Geroski, 1992). Following that intuition, this paper provides a model showing that, in some imperfectly competitive contexts, vertical integration is a second best solution, socially preferable to horizontal collusion in R&D.

Recent literature has analysed how spillovers influence R&D co-operation or competition strategies of the firms in detail. The pioneering paper by d'Aspremont and Jacquemin (1988) considers a two stage game where Cournot behaving firms undertake cost-reducing R&D. In the presence of considerable spillovers, co-operation increases R&D expenditure level. This result is due to several opposite factors. First, since firms compete in the same market they are reluctant to invest in R&D in order not to make the rivals benefit from the spillovers. Second, each firm has an incentive to behave as a free rider, in order to exploit the positive externality of spillovers. Third, co-operation at the final stage implies lower levels of production and reduces R&D duplications. Moreover, in the case the firms buy innovation from an

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intermediate market, co-operation increases firms' monopsony power in that market. Suzumura (1992) shows that, since the first effect and the second one compete against the third one, the non-cooperative equilibrium level of R&D is socially excessive, whereas the co-operative R&D effort is insufficient. He also generalises, from d'Aspremont and Jacquemin's approach, to a wider class of Cournot oligopolistic industries. Kamien - Muller - Zang (1992) analyse Bertand competition, achieving similar results. They focus on several competitive or co-operative settings for R&D production. De Bondt - Veugelers (1991) investigate the strategic nature of R&D investments and its relationships to the spillovers. The authors propose a sequential game in which the investor, not only takes into account the strategic effect of the investment, but also internalises the spillovers. Thus, in case of negative externality, co-operation causes R&D expenditure to decrease.

This literature does not provide a specific analytical framework for the cases in which R&D is supplied by an external upstream innovator. About this case the models mentioned above can only suggest reasonable intuitions. The literature on vertical integration has not analysed this issue where one could find some criticism of the standard vertical foreclosure argument against vertical integration[1]. If the intermediate input generates horizontal spillovers, the integrated firm could find convenient not to completely foreclose the downstream customers in order to benefit its downstream section from the positive spillovers. This incentive could be reinforced if, in the case of non-linear cost function of the input, the integrated firm, by selling to the independent users, can save on the internally transferred amount of input.

This paper presents a simple model capable of capturing these elements. I present a two stage game where R&D is purchased by the firm from an intermediate market of innovation. At the second stage, the R&D strategies define the final competition among users. At the first stage, R&D exchange takes place in a monopolistic market. By explicitly considering the market of innovation, the model aims at analysing whether the incentive to vertical integrate R&D depends on the strategic impact on the final competition, and ultimately on the scope for a potential control over the technological spillovers. I find out an equilibrium which presents some appealing welfare arguments in favour of permissive anti-trust policy on vertical integration in R&D markets.

[1] The phenomenon of the vertical foreclosure has been largely discussed in the analysis of the welfare consequences of vertical integration. See S.A. Salinger (1988), J.L. Hamilton - S.B. Lee (1986) and G. Bonanno - J. Vickers (1988). The possibility of equilibria that involve refusal to deal with rival downstream firms is controversial. J.A. Ordover - G. Saloner - S.C. Salop (1990) develop a complex model that includes foreclosure threats and potential counter-strategies. Vertical foreclosure emerges with certainty in a symmetric Bertrand competition. Nevertheless, the model can degenerate in a prisoner dilemma if the independent firm can bid for the same upstream supplier.



## 1. The model

Consider an industry with two firms, $D_1$ and $D_2$, producing a highly technological final good and competing *à la* Cournot. R&D is the unique variable production factor and it is bought from a monopolist innovator, U. Let $x_i$ and $q_i$ denote $D_i$'s amount of R&D and output respectively ($i = 1,2$). Suppose that increasing amounts of R&D always include new knowledge which can be exploited by different users. Thus each firm learns from imitating the basic innovative knowledge sold to the rival[2]. Let $\beta$ identify the symmetric spillover parameter ($0 \le \beta \le 1$); then $X_j = x_j + \beta x_i$ ($i \ne j$) is the effective magnitude of the technological factor at $D_j$'s disposal.

Let the production function be the following[3]

$$q_i = c\,(x_i + \beta x_j) \tag{1}$$

One inverse linear demand function for the final good is the following

$$p = a - b\,(q_1 + q_2) \tag{2}$$

The upstream monopolist charges $p_m$ for R&D, thus $D_i$'s implicit cost function is the following

$$C_i = p_m x_i \tag{3}$$

I assume that production of R&D presents decreasing returns to scale with constant marginal costs[4]; an *ad hoc* explicit production cost function is

$$C_m = \frac{1}{2} m x^2 \tag{4}$$

where $x = x_1 + x_2$.

[2] This means that $D_i$ benefits from the spillovers generated by the entire amount of $x_j$ and not only by $(x_j - x_i)$, where $i, j = 1,2$ and $i \ne j$. This concept of spillover rules out potential duplications of R&D.

[3] Let all the parameters in the following equations be positive.

[4] In Section 2.3, I will show that the incentive to vertical foreclosure depends on $m$.

A classical result of the analysis of R&D suggests that with a unique production factor and monopoly intermediate market, like in this model, one observes the largest amount of vertical externality. However, these two simplifying hypotheses do not entail a big generality loss, since vertical externality continues to occur also with small imperfections of the intermediate market and variable proportions, provided that the inputs are not perfectly substitutable.

### 1.1 *Non-Cooperative and Decentralised Equilibrium*

Thanks to its monopoly power, U can fix $p_m$ at the first stage[5]. At the second stage, $D_1$ and $D_2$ compete choosing $q_1$ and $q_2$ respectively. Because of the unique input hypothesis which sets a one-to-one relationship between $x_i$ and $q_i$ $(i = 1,2)$, $D_i$*'s* strategies can be expressed by $x_j$*'s*.

Let's compute the perfect Nash equilibrium for this game, starting from the second stage.

*a) Second Stage*

$D_1$ and $D_2$ maximise their own profit functions under the zero-conjectural variation hypothesis:

$$\pi_1 = [a - b\,[q_1(X_1) + q_2(X_2)]] \cdot q_1(X_1) - p_m x_1 \tag{5}$$

$$\pi_2 = [a - b\,[q_1(X_1) + q_2(X_2)]] \cdot q_2(X_1) - p_m x_2 \tag{6}$$

FOC's system is

$$\begin{cases} \dfrac{\partial \pi_1}{\partial x_1} = ca - 2bc^2(1+\beta)(x_1+\beta x_2) + bc^2 x_2(1-\beta^2) - p_m = 0 \\ \dfrac{\partial \pi_2}{\partial x_2} = ca - 2bc^2(1+\beta)(x_2+\beta x_1) + bc^2 x_1(1-\beta^2) - p_m = 0 \end{cases} \tag{7}$$

The Nash-Cournot equilibrium is

$$\left\{ x2^* = \frac{ca - p_m}{bc^2[(2+\beta)^2 - 1]};\ x1^* = \frac{ca - p_m}{bc^2[(2+\beta)^2 - 1]} \right\} \tag{8}$$

[5] One could observe that this assumption is not appropriate since monopoly requires a very large number of customers. However, if the upstream innovator can supply other R&D users in different downstream brands, then $D_1$ and $D_2$ lose any monopsony power; moreover, if in these different brands the derived demand function for innovation is inelastic enough, the monopolist takes mainly $D_1$ and $D_2$'s demand into account while fixing $p_m$.



Note that $\dfrac{\partial x_i^*}{\partial p_m} < 0$ $(i = 1, 2)$; this is a sufficient condition for double marginalisation at the first stage. Note also that $\dfrac{\partial x_i^*}{\partial \beta} < 0$: horizontal externality reduces R&D expenditure. This result reflects the free riding behaviour of the final users of R&D[6]. It is essentially due to a couple of effects: a *pure free riding effect*, caused by the received positive externality, and a *competition effect*, due to the produced spillovers. Thus, not only is $D_i$ willing to reduce $x_i$ to profit by the positive spillovers of $x_j$, but is $D_i$ also willing to reduce $x_i$ in order not to favour $D_j$. In Fig. 1, increasing $\beta$ tends to shift downwards and to steepen $D_1$'s inverse reaction function $rf_1$[7].

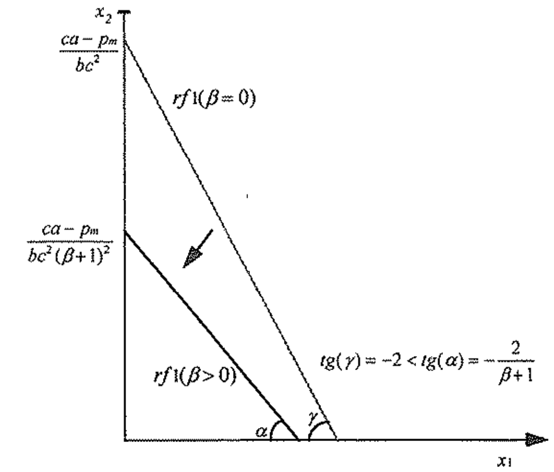


Fig. 1

[6] C. D'ASPREMONT - A. JACQUEMIN (1988) had shown similar characteristic of the R&D competition with spillovers. K. SUZUMURA (1992) has generalised those characteristics, considering a wider class of oligopolistic industries.

[7] With high spillovers firms become more reactive to rivals' strategies. This confirms De Bondt and Veugelers's idea that toughness of strategic investments in R&D is related to the value of the spillover parameter. Note also that, if $\beta = 1$, $D_1$'s and $D_2$'s reaction functions coincide. In this extreme case one would have infinite equilibria. Nevertheless, the symmetric equilibrium still continues to be the most reasonable one because, as $\beta \to 1$, it represents the limit of the reaction functions' intersection. Moreover, since the firms have identical power in influencing each other, any asymmetric equilibrium does not seem to be suitable.

Looking at the iso-profit curves, a special trade-off emerges in the strategy choice. For example, consider $D_1$'s explicit profit function for a given amount of profits, $\pi_1(x_1, x_2) = K^{\circ}$

$$x_2 = \frac{1}{2bc^2\beta(1+\beta)}[ca\beta - bc^2 x_1(1+\beta)^2 \pm A] \tag{9}$$

with:

$$A = c\sqrt{a^2\beta^2 + 2abc\beta x_1(1-\beta^2) + b^2c^2x_1^{\,2}(1-\beta^2)^2 - 4b\beta pmx_1(1+\beta) - 4b\beta(1+\beta)K^{\circ}}$$

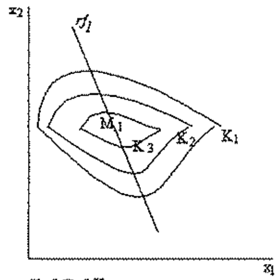


Fig. 2a

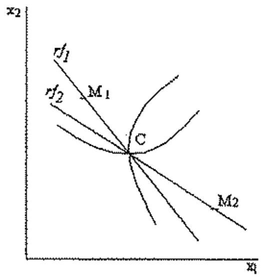

Fig. 2b

Fig. 2a shows function (9) for several values of the profit level $K$. In $M_1$ $D_1$ reaches the global maximum profit. Unlike the standard Cournot competition without spillovers, $M_1$ does not lie on $x_1$'s axis because $D_1$ balances the profit increase caused by increasing $x_1$ against the profit increase due to the spillovers from larger $x_2$ and, thus, smaller $x_1$ (pure free-riding and competition effects on profits). In general, the higher $\beta$, the stronger these effects. Thus, as $\beta$ increases $(i \neq j; i,j = 1,2)$ $D_i$'s global maximum profit is reached at an intermediate point, $M_i$ which moves towards the $x_j$'s axis. In Fig. 2b a competitive setting with high spillovers ($M_1$ is above C) has been drawn.

*b) First Stage*

$\sum_i x_i{}^*(p_m)$ represents the global industry's derived demand for R&D. From the second stage of the game, the inverse demand function for R&D is the following

$$p_m = ac - \frac{bc^2[(2+\beta)^2 - 1]}{2}x \tag{10}$$



with $x = x_1 + x_2$.

Using (10), U's profit function is the following

$$\pi_m(x) = \left[ac - \frac{bc^2((2+\beta)^2 - 1)}{2}x\right]x - \frac{1}{2}mx^2 \tag{11}$$

Perfect equilibrium R&D quantity and price can be computed to be

$$x_m{}^* = \frac{ac}{bc^2((2+\beta)^2 - 1) + m} \tag{12}$$

$$p_m{}^* = \frac{ac[bc^2((2+\beta)^2 - 1) + 2m]}{2bc^2((2+\beta)^2 - 1) + m} \tag{13}$$

Not surprisingly, increasing $\beta$ shifts downwards and steepens the courve from equation (10). Since the steeper the demand for input the larger the monopolist's mark-up, a crucial relationship between vertical and horizontal externalities arises: higher technological spillovers imply larger double marginalisation. One could compute the monopolist's profit and observe that $\frac{\partial \pi_m{}^*}{\partial \beta} < 0$. Despite the higher rigidity of the factor demand, the reduction of total R&D demand, due to spillovers, depresses the market of innovation and causes $p_m{}^*$ to decrease. Monopolist's equilibrium profit is negatively influenced by the spillovers.

## 1.2 *Co-operation at the Final Stage*

Since in this model final quantity competition is directly played by choosing $x_i$ $(i = 1,2)$, it is not possible to distinguish between pre-competitive R&D co-operation and full collusion[8]. Thus, R&D co-ordination implies also final monopoly, whose joint profit function is the following:

$$\pi_c = \pi_1 + \pi_2 = [a - bc(1+\beta)(x_1 + x_2)] \cdot c(1+\beta)(x_1 + x_2) - p_m(x^1 + x_2) \tag{14}$$

The curve of the possible collusive agreements that maximise (14) is the following:

[8] This distinction has been drawn by M.L. KATZ (1986), by C. D'ASPREMONT - A. JACQUEMIN (1988) and can be found also in other more recent papers.

$$x_1 = \frac{ac(1+\beta) - p_m}{2bc^2(1+\beta)^2} - x2 \qquad (15)$$

Co-ordination in R&D completely solves the free-riding problem, then the intermediate demand for R&D is expected to raise provided that the monopoly incentive to reduce the final production is not too strong. In Fig. 3, (15) is the line crossing $M_1$ and $M_2$. This figure illustrates a case with very large spillovers which cause the line to be above point C which represents the second stage Cournot equilibrium. In this case, each possible collusive agreement would imply a larger amount of total R&D expenditure (for example, point A)[9].

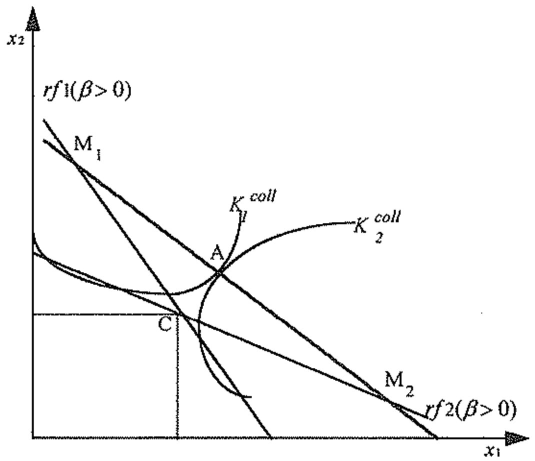


Fig. 3

The perfect equilibrium solutions of the game follow

$$x_1^c = x_2^c = \frac{ca(1+\beta)}{8c^2 b(1+\beta)^2 + m} \qquad (16)$$

$$p_m^c = \frac{ac(1+\beta)[2c^2 b(1+\beta)^2 + m}{4c^2 b(1+\beta)^2 + m} \qquad (17)$$

[9] Alternatively, if spillovers are not large enough, monopolisation effect is stronger than free riding removal; then the agreement point be in the South-western region with respect to point C, with lower equilibrium amount of R&D. See also the comparisons in section 2.3 below, in which the role of marginal cost of R&D is considered too.



Note that $\frac{\partial p_m^c}{\partial \beta} > 0$ and $p_m^c > m$. Horizontal collusion at the downstream level solves the free riding problem, but the final price still continues to be double-marginalised. The higher productivity of R&D due to the co-ordinated exploitation of spillovers increases the absolute amount of the intermediate mark-up caused by the vertical externality. In Section 1.3 I will show that this makes downstream collusion less attractive than vertical integration in many cases.

1.3 *Vertical Integration*

Assume that one downstream firm, say $D_1$, and U merge into a centralised firm F. The structure of the game changes radically. By controlling $p_m$, F can exploit a leadership advantage[10]. This helps to solve both the pure free riding and the double marginalisation problems. The removal of the vertical externality *via* vertical integration entails also the removal of horizontal externality. Nevertheless, the standard incentive to foreclose $D_2$ from R&D supply emerges. Moreover, in the presence of technological spillovers the incentive to reduce R&D production could be reinforced for fear of making the independent firm benefits by the spillovers from the internally exchanged R&D. However, F balances those incentives against the opposite incentive to reduce the intermediate market price in order to increase the amount of R&D purchased by $D_2$ and take advantage of the positive spillovers which increase, without additional cost, the effective magnitude of the technological input used by the downstream section. The model shows that the latter incentive always prevails and complete vertical foreclosure never occurs provided that spillovers are positive and marginal costs of R&D are non-zero.

*a) Second Stage*

$D_2$ chooses $x_2$ in order to maximise his own profit function

$$\pi_2 = [a - bc(1+\beta)(x_1 + x_2)]\, c\,(x_2 + \beta x_1) - p_m x_2 \qquad (18)$$

$D_2$'s demand for R&D is the following

$$x_2 = \frac{ac - p_m - [bc^2(1+\beta)^2]\, x_1}{2bc^2(1+\beta)} \qquad (19)$$

[10] A game where F fixes $p_m$ at the first stage and $x_1$ at the second one generates the same results as an alternative game in which F sets both $p_m$ and $x_1$ at the first stage.

(19) represents a sort of reaction function that the leader F internalises at the first stage.

*b) First Stage*

F maximises the following integrated profit function by fixing both $p_m$ and $x_1$

$$\pi_F = [a - bc\,(1+\beta)\,(x_1 + x_2)] \cdot c\,(x_1 + \beta x_2) + p_m x_2 - \frac{1}{2}\, m\,(x_1 + x_2)^2 \quad (20)$$

The subgame perfect equilibrium solutions follow

$$x_1^{vi} = \frac{a\,[2bc^2\,(\beta^3 + 2\beta^2 - 1) + \beta m]}{2bc\,[2bc^2\,(1+\beta)\,(\beta^3 + 2\beta^2 - 1) + m\,(\beta^2 - 1)]} \quad (21)$$

$$x_2^{vi} = \frac{\beta m a}{2bc\,(1+\beta)\,[2bc^2\,(1 - \beta^3 - 2\beta^2) + m\,(1-\beta)]} \quad (22)$$

The vertical integration equilibrium seems quite appealing to a social planner as a second best solution for maximising the consumers' welfare. Vertical integration does not entail final monopolisation; it also avoids pure free riding failures and double marginalisation, at least for internally transferred R&D. In most cases vertical integration in R&D increases total equilibrium R&D and final production more than R&D co-operation or competition. In order to show this I compare the equilibrium amounts of R&D with different values of the spillover and marginal cost parameters.

Let us consider $x^*_m$, $x^c = x^c_1 + x^c_2$ and $x^{vi} = x^{vi}_1 + x^{vi}_2$ from (12), (16) and (21)-(22) respectively. Note that:

a) if $m$ is sufficiently high or $\beta \to 0$, then $x^*_m < x^c$: in the case of large spillovers R&D co-operation is socially preferable to final competition because it solves the free riding problem, and negative effects of final monopolisation are limited by cost savings;

b) if $m$ is low or $\beta \to 0$, then $x^{vi}_1 > x^*_m$ : with low spillovers or low marginal costs (but $\beta$ sufficiently high), vertical integration performs better than final competition, because it solves the free riding problem and, partially, the double marginalisation phenomenon;

c) if $m$ is low or $\beta$ is sufficiently high, $x^{vi}_1 > x^c$: with high spillovers, vertical integration performs better than final collusion, since the latter implies final monopolisation without large cost savings.

Summarising these results, if spillovers are not very high, vertical integration is preferable to final competition with upstream monopoly because it



limits the number of successive distortions in the production chain. In the case of large spillovers, vertical integration is better because it rules out the free rider behaviour avoiding the risk of final monopolisation.

## Conclusions

This paper has investigated how the obstacles to appropriability of the gains from innovation can be removed by horizontal or alternatively by vertical monopolisation. When there are distortions in competition in the upstream market of innovation, vertical integration seems to be the preferable solution in most cases, from the consumers' viewpoint. Unlike the R&D co-operation, vertical integration in R&D is not in high favour with the European Anti-trust Authority. This paper suggests some strong arguments in support of a special permissive treatment of vertical integration in research activities.

The robustness of the results rests on certain features of the technology and of the market structure. First, in this paper the positive effects of vertical integration have been emphasised by the hypotheses of upstream monopoly and unique production function. If one considers input substitutability or smaller upstream market distortions, he should expect that the main conclusions are weaken. Nevertheless they continue to be valid for appropriate values of the parameters. Second, the model also assumes that bilateral monopoly in the intermediate market can never occur, not even after the collusion. In fact, the cartel exerts higher monopsony power on the intermediate market; this would reduce the impact of double marginalisation, improving the welfare performances of the horizontal collusion. Third, one could model the upstream innovation supply as an oligopoly rather than a monopoly. In that case, the competition among the independent upstream suppliers would reduce the gains from removing double marginalization by vertical integration. Finally, I have assumed quantity competition. However, when the spillovers increase, the differences in the strategic impact of investments, in the Cournot and in the Bertrand cases, weaken. The downstream section of the integrated firm bears the lowest cost, then the independent rival is less tough. In the case of strategic complements, this would favour an inoffensive behaviour, and a more accommodating pricing should result. However, it remains to demonstrate those intuitions. Richer formulations of the model should also take into account more sophisticated forms of vertical contract and independent firm's bid.

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