Vertical integration, technological choice and foreclosure

Eric Avenel*
*EUREQua, Université de Paris I Panthéon-Sorbonne***

1 Introduction

The concept of vertical foreclosure is central to the strategic analysis of vertical integration and, as such, is an important issue in Industrial Organization. Following Ordover, Saloner and Salop (1990), we define it as "the exclusion that results when unintegrated downstream rivals are foreclosed from the input supplies controlled by the firm that integrates". To illustrate this definition, consider a monopolist producing an intermediate good and selling it to several downstream firms competing *à la Cournot* on the final market. If the monopolist is vertically integrated into the downstream industry, it refuses to supply its non-integrated rivals and monopolizes the final market[1].

The extension of the theory of vertical foreclosure to successive oligopoly models is far from straightforward and constitutes a very controversial issue. In this article, we consider, like Ordover, Saloner and Salop (1990), an upstream symmetric Bertrand duopoly and, as regards the downstream

* I am grateful to D. Encaoua, A. Perrot, P. Rey, J.-P. Ponssard, C. Barlet and two anonymous referees for helpful comments on earlier versions of the paper.

** Maison des Sciences Economiques, 106-112, Boulevard de l'hôpital, 75647 Paris Cedex 13. France. e-mail: avenel@univ-paris1.fr

[1] This type of foreclosure is illustrated by several antitrust cases. In an Australian case, *Queensland Wire Industries ("Q.W.I.") Proprietary Limited v. The Broken Hill Proprietary ("B.H.P.") Company Limited and another (1989)*, Judge Deane sums up the facts as follows: "Here, B.H.P. has refused, otherwise than at an unrealistically high price, to supply the appellant ("Q.W.I.") with a steel product ("Y-bar") produced by B.H.P.'s rolling mills. [...] The explanation of B.H.P.'s effective refusal to supply Y-bar to Q.W.I. is that there is no other local producer or wholesaler of Y-bar and B.H.P. desires to prevent Q.W.I. from manufacturing and selling star picket fencing posts (produced from Y-bar) in competition with the second respondent ("A.W.I."), which is a wholly owned subsidiary of B.H.P."

industry, a Bertrand duopoly with differentiated goods[2]. Under these assumptions, there is no double-marginalization in the absence of vertical integration[3] and the profitability of vertical integration completely relies on strategic anticompetitive effects. The key point in such models is to assert whether vertical foreclosure takes place under partial vertical integration and whether this structure emerges as an equilibrium of a properly defined merger game. Ordover, Saloner and Salop (1990) claims that foreclosure emerges in equilibrium as long as the integrated firm can commit on the intermediate price it offers. This is equivalent to assuming that the integrated firm is a Stackelberg leader. However, it is not clear why it should be so, as Reiffen (1992) and Hart and Tirole (1990) pointed out. It is all the less clear as it is profitable for the firm to deviate from the foreclosure strategy and sell a small, positive amount of intermediate good. Such deviation opportunities destroy any market equilibrium but the market equilibrium obtained without vertical integration. Vertical integration has no impact on market prices in this model unless one assumes a particular commitment capability for integrated firms. In the present paper, we claim that this unsatisfactory result is due to the fact that integrated firms are (implicitly) assumed to be similar to non-integrated firms as regards the technology they use. We show that the introduction of a technological choice in the model solves the commitment problem. Indeed, an integrated firm can commit to foreclosure by adopting a technology that is not compatible with the technology used by non-integrated firms. This choice can be profitable and constitute an equilibrium strategy.

More precisely, we claim that there is a fundamental difference between integrated and non-integrated firms as regards the technological choice. Whereas non-integrated firms can only use the technology based on the standard intermediate good traded on the market – we call "standard" this technology –, integrated firms can also adopt a technology based on an intermediate good different from the standard intermediate good and, for some reason, not compatible with the standard technology – we call "non-standard" such a technology. If the incompatibility is so strong that the non-standard good cannot be adapted to the standard technology, the adoption of a non-standard technology implies that the integrated firm will not participate to the intermediate market and, thus, will foreclose its downstream rivals. However, the degree of incompatibility needs not be so strong and we consider the more general situation where it is possible to adapt the non-standard good to the standard technology. Of course, this adaptation is costly and this cost is a measure of the degree of incompatibility. Introducing the distinction between standard and non-standard technologies in a model that is otherwise relatively close to Ordover, Saloner and Salop (1990) leads

[2] In this respect, our model is similar to Colangelo (1995), but Colangelo examines the very different issue of the pre-emptive nature of integration in a model where both vertical and horizontal integration can occur. For a comment on this paper, see Avenel (1996).

[3] For an analysis of vertical foreclosure in a model with double-marginalization, see Salinger (1988), Schrader (1994) and Gaudet and Van Long (1996).

to a very significant change in the analysis and allows us to establish a set of conditions for the emergence of vertical foreclosure in equilibrium in the absence of any particular assumption as regards the commitment capability of integrated firms. In particular, we don't assume that integrated firms can commit to the price they charge on the intermediate market.

The article is organized as follows. After the presentation of the model (section 2), we show (in section 3) that, as well as the adoption of a non-standard technology leads to the foreclosure of downstream rivals, the converse is true, that is, if an integrated firm adopts the standard technology, it doesn't foreclose its downstream rivals[4]. This point being established, it remains to see whether integrated firms indeed adopt a non-standard technology and whether partial integration with adoption of a non-standard technology occurs in equilibrium. This is done in section 4. Section 5 concludes.

2 The model

The model is a four stage game. In the first stage, both pairs of upstream-downstream firms can merge. Then, in stage 2, integrated firms (if there is any) have to choose between adopting the standard technology or a non-standard technology. After stage 2, the structure of the industry is determined. In stage 3, non-integrated upstream firms and integrated firms compete in price on the intermediate market. Finally, in stage 4, non-integrated downstream firms and integrated firms also compete in price. This section is devoted to a more detailed presentation of the different stages of the game and of the distinction between standard and non-standard technologies.

2.1 Stage 1 : Merger game

We denote upstream and downstream firms respectively by $(U_i)_{i=1,2}$ and $(D_i)_{i=1,2}$. In this stage, each pair of firms, (U_i, D_i) decides whether to merge or not. Clearly, the upstream firm can make a profitable and acceptable merger offer to the downstream firm, and vice versa, if and only if the merger increases their joint-profits. We do not model the negotiations between upstream and downstream firms, but assume that they are efficient, so that integration occurs if and only if the profit of the integrated structure is higher than the separated firms' joint-profits, both profits depending on the rivals' decision. As a consequence, stage 1 is a two-players game. There is a positive integration cost, denoted by I, which represents both legal costs

[4] This may not be true if an integrated firm is subject to a capacity constraint or, more generally, if the marginal cost of producing the intermediate good increases when the output increases. However, as most articles in this field, we ignore this issue and assume a constant marginal cost of production.

and the costs generated by the reduction of the subordinate manager's incentives.

After stage 1, there are four possible structures for the industry : NI (no integration), FI (full integration) and $PI_i, i = 1, 2$ (partial integration by U_i and D_i). We denote by F_i the result of a merger between U_i and D_i.

2.2 Stage 2 : Technology adoption

We distinguish between a "standard" technology and "non-standard" technologies. The standard technology is based on an intermediate good commonly traded on the market. Due to the existence of this market, the assets used in the production and the transformation of the (standard) intermediate good are not specific to a particular commercial relation. The standard technology can thus be adopted by both integrated and non-integrated firms. To the contrary, because of the incompatibility of a particular non-standard intermediate good with the standard technology and with other non-standard technologies, the assets used in the production and the transformation of this good are specific to the commercial relation between the upstream firm that produces the good and the downstream firm that transforms the good into the final good. As a consequence, we assume that, due to the incomplete nature of contracts, the adoption of a non-standard technology is possible only for vertically integrated firms.

Our approach of the technological choice of firms relies on empirical facts collected from several industries and, notably, from the pulp and paper industry. The production of paper is essentially a two-steps process. In the first step, pulp is produced from wood or recycled paper. In the second step, it is transformed into paper. If the production of pulp and the production of paper take place at different locations, which is common, the pulp, that initially is a liquid, must be transformed into (dry) "market pulp". There is a worldwide market on which upstream and downstream firms, some of them integrated, some others not, trade market pulp. If the pulp and the paper are produced at the same location, which is also common[5], the pulp is treated in its liquid form and market pulp plays no role in the process. Of course, the requirement that pulp and paper are produced at the same location induces a site specificity of upstream and downstream assets. Vertical integration is the rule for firms using this technology. Clearly, market pulp and liquid

[5] In the recent period, there has been a trend toward more integrated plants in the pulp and paper industry. There is no doubt that the evolution of transportation costs and tariffs, as well as the development of the use of recycled paper in the production of pulp explain for a large part this trend, but it is also clear that firms are aware of the strategic implications of this evolution. In particular, it is clearly not favorable to non-integrated downstream firms. More generally, technological choices result from many effects that are not only strategic. Essentially, non-standard technologies may be more efficient. Our point is that even if the adoption of a non-standard technology is motivated by the desire to lower costs, it also has a strategic effect on the commercial relations between the integrated firms and the other firms. This effect must be taken into account in the evaluation of non-standard technologies. This is what we focus on in this article, thus abstracting from potential efficiency gains.

pulp respectively satisfy our definition of a standard and a non-standard intermediate good.

As the standard technology is the technology that non-integrated firms use, an integrated firm that adopts this technology can either buy (and use) or sell the standard intermediate good just as non-integrated firms do. This is not the case with a non-standard technology. Indeed, the intermediate good associated with a non-standard technology is not adapted to the standard technology. As a consequence, a non-integrated downstream firm willing to use a non-standard good has to adapt it to the standard technology[6]. We assume that this adaptation induces a unit cost (denoted by δ). In the same way, an integrated firm using a non-standard technology could use the standard intermediate good after adapting it, but this opportunity plays no role in our analysis, because it cannot be profitable for an integrated firm[7]. As a consequence, we just need to consider the possibility for non-integrated downstream firms to purchase, adapt and use a non-standard intermediate good.

Except for the adaptation cost, we assume that the variable cost of producing the intermediate good and the final good is the same for the standard technology and for non-standard technologies. However, we allow for a difference in the fixed costs. Normalizing the fixed cost associated with the standard technology to zero, we denote by E the fixed cost associated with non-standard technologies. As E is in fact the difference between two fixed costs, it may be positive or negative. However, we just consider the more interesting case where E is positive[8].

We assume that the technological choice is observable and irreversible, so that the type of technology used by integrated firms is common knowledge in the following stages of the game.

2.3 Stage 3 : Upstream competition

Competition on the intermediate market is *à la Bertrand*. The standard intermediate good is homogeneous and, once a non-standard good has been adapted to the standard technology, it is a perfect substitute of the stan-

[6] Note that we could distinguish between two possibilities as regards the firm that supports the adaptation cost when an integrated firm using a non-standard technology supplies a non-integrated downstream firm. We think that it strongly varies across industries, but in our model, given our assumption of Bertrand competition on the intermediate market, the two possibilities are equivalent. In both cases, the total cost for a non-integrated firm of purchasing one unit of good from the integrated firm and transforming it into the final good is $\delta + m$, where m is the integrated firm's price-cost margin on the intermediate market. We assume without loss of generality that the downstream firm supports the cost.

[7] Such purchases would just rise the downstream cost, compared to the use of internally produced intermediate good.

[8] As the adoption of a non-standard technology increases the gross profit of an integrated firm facing non-integrated competitors and leaves unchanged the gross profit of an integrated firm facing an integrated competitor, it would emerge in all equilibriums in stage 2 if the difference E in fixed costs was in favor of non-standard technologies.

dard good[9]. Upstream firms, either integrated or not, have the same marginal cost, which is constant, equal to zero. Integrated downstream firms thus procure internally at zero cost, whereas non-integrated downstream firms rely on the intermediate market, thus paying $w = \min(v_1, v_2)$ for the intermediate good, where v_i is the price offered by U_i.

2.4 Stage 4 : Downstream competition

Downstream firms sell differentiated (substitute) goods. The strategic variables are the prices, $(p_i)_{i=1,2}$. There are no downstream variable costs other than the price for the input and the eventual adaptation cost.

We consider the following demand functions :

$$q_i = \alpha - p_i + \gamma p_j \; ; \; i = 1,2 \; ; \; i \neq j \; ; \; \alpha > 0 \; ; \; 0 \leqslant \gamma < 1 \tag{1}$$

We restrict our attention to substitute goods, because foreclosure is not an issue for complement goods. Indeed, the logic of foreclosure is that reducing competition on the intermediate market leads to an increase in the intermediate price and thus in non-integrated downstream firms' costs. Those firms increase their price and, when goods are substitutes, this increases the demand for the integrated firm's good. To the contrary, when goods are complements, then downstream firms don't have an incentive to rise their rival's price, as this reduces the demand for their own good and finally reduces their profit. Foreclosure thus cannot be a profitable strategy.

3 Foreclosure and the standard technology

In this section, we briefly present the equilibrium that obtains on the intermediate and the final market in the absence of integration and the equilibrium that obtains when just one pair of firms is integrated and uses the standard technology. We show that these two structures are just one and the same as regards market strategies in equilibrium.

3.1 No Integration

Both downstream firms are independent and rely on the intermediate market. Their marginal cost is thus equal to the price w they pay for the intermediate good. As regards the determination of w, Bertrand competition

[9] As integrated firms have no incentive to trade with each other in this model (each firm produces the intermediate good at zero cost), we don't examine the issue of the adaptation of a non-standard good to another non-standard technology.

leads to $v_1 = v_2 = 0$. Upstream firms make no profit and downstream profits are given by

$$\pi_{D_i}^{NI} = \left(\frac{\alpha}{2-\gamma}\right)^2, \ i = 1, 2 \tag{2}$$

3.2 Partial Integration with a standard technology

We now consider the situation where the pair of firms (U_i, D_i) is integrated and uses the standard technology. D_i procures internally at zero cost, while D_j relies on the intermediate market, supporting the intermediate price w. Downstream prices are given by

$$p_i(w) = \frac{\alpha}{2-\gamma} + \frac{\gamma w}{(2-\gamma)(2+\gamma)} \tag{3}$$

$$p_j(w) = \frac{\alpha}{2-\gamma} + \frac{2w}{(2-\gamma)(2+\gamma)} \tag{4}$$

Determining the quantities is straightforward :

$$q_i(w) = p_i(w) \tag{5}$$

$$q_j(w) = p_j(w) - w = \frac{\alpha}{2-\gamma} + \frac{\gamma^2 - 2}{(2-\gamma)(2+\gamma)} w \tag{6}$$

It is interesting for what follows to note that, whereas the effect of an increase in w on the joint profits of U_j and D_j is not clear-cut, it appears that, for a given w, U_j and D_j as a whole are better off when goods are closer substitutes[10], because the price increase is more important and the quantity decrease is less. They thus have a lower incentive to proceed to a "reactive" merger.

Let us now determine the intermediate price. F_i's profit is the sum of downstream and upstream profits. On the downstream market, F_i makes a profit equal to $p_i(w)q_i(w)$. On the final market, it makes a profit only if $v_i \leqslant v_j$. Otherwise, there is no demand addressed to F_i. To the contrary, if $v_i < v_j$, the entire demand is addressed to F_i, which makes a profit equal to $wq_j(w)$. Finally, if $v_i = v_j$, D_j's demand is shared between U_i and U_j according to a rule $(\alpha; 1-\alpha)$, with $0 \leqslant \alpha \leqslant 1$. As a whole, F_i's profit is given by :

$$\pi_{F_i} = p_i(w)q_i(w) + wq_j(w)1_{v_i=w<v_j} + \alpha w q_j(w) 1_{v_i=w=v_j} - I \tag{7}$$

[10] Of course, it doesn't necessarily mean that non-integrated firms are better of for close substitutes than for relatively independent goods. Indeed, determining the total effect of γ on non-integrated firms' profits requires us to determine the endogenous intermediate price w.

Contrary to F_i, U_j is present only on the intermediate market. It makes a profit equal to

$$wq_j(w)1_{v_j=w<v_i} + (1-\alpha)wq_j(w)1_{v_j=w=v_i} \tag{8}$$

Clearly, there is no equilibrium such that $0 < v_i = w < v_j$. Indeed, U_j makes no profit and can get a positive profit by deviating and offering $v_j' \in]0; v_i[$. The point is that there is also no equilibrium such that $0 < v_j = w < v_i$. Indeed, in such a situation, F_i gets

$$p_i(w)q_i(w) = \left(\frac{\alpha}{2-\gamma} + \frac{\gamma w}{(2-\gamma)(2+\gamma)}\right)^2 - I \tag{9}$$

Offering $v_i' = w(1-\varepsilon)$, with ε arbitrarily small, F_i gets

$$\left(\frac{\alpha}{2-\gamma} + \frac{\gamma w(1-\varepsilon)}{(2-\gamma)(2+\gamma)}\right)^2 + w(1-\varepsilon)\left(\frac{\alpha}{2-\gamma} + \frac{\gamma^2-2}{(2-\gamma)(2+\gamma)}w(1-\varepsilon)\right) - I \tag{10}$$

The first part of (10) is F_i's downstream profit, which is slightly reduced, and the second part of (10) is the profit that F_i makes on the intermediate market by getting D_j's demand. This is obviously a profitable deviation. The same argument explains why there is no equilibrium such that $w = v_i = v_j > 0$. To the contrary, $w = 0$ clearly is an equilibrium for stage 3. Indeed, both firms make no profit on the intermediate market, but none of them has a profitable deviation. $w = 0$ is thus the unique equilibrium. Note that it is similar to the equilibrium we found in the preceding subsection, with no integration at all.

3.3 Conclusion

The results of this section show that there is nothing like foreclosure under partial integration in this model if the integrated firm adopts the standard technology. F_i engages in upstream competition, although this, in the end, makes integration unprofitable, because it cannot resist the temptation of serving D_j's demand. This leads us to the conclusion that foreclosure, in this model, can only result from the adoption of a non-standard technology or, in other words, that, absent the technological choice, no vertical foreclosure can arise.

What is more, vertical foreclosure will have a significant impact only if a pair of firms remains non-integrated. Indeed, the different types of FI structures are similar to the NI structure as regards market equilibrium, no matter what technology the two integrated firms adopt. Two firms that have access to their intermediate good at a zero price compete on the final market, just as under NI. They thus offer the same prices for the final good and sell the same quantities, making the same (gross) profits. The difference between FI and NI is just in the way upstream and downstream firms share the profits. One should also notice that, under FI, both firms adopt the standard technology in stage 2, as adopting a non-standard technology induces a supplementary cost, but doesn't increase the gross profit, thus reducing the net profit.

4 The complete model

Given the results of the previous section, we just have to solve the market competition stages for the "PI with a non-standard technology" structure. In a first step, we assume that the adaptation cost is low and determine the market equilibrium. This allows us to determine the impact of the adoption of a non-standard technology on the different firms' profits and to evaluate the profitability of this technology for an integrated firm facing non-integrated competitors (section 4.1). Then, we solve the first stage of the game and show that partial integration with foreclosure emerges as the unique equilibrium over a large range of values of the parameters (section 4.2). In a second step, we treat the case of a high adaptation cost and show that a minimal degree of substitutability between final goods is required for vertical foreclosure to emerge (section 4.3). Finally, we propose a synthesis of the results (section 4.4).

4.1 Does foreclosure emerge under partial integration ?

Suppose that in stage 1, U_i and D_i merge, while U_j and D_j stay separate, and that F_i adopts a non-standard technology. Prices and quantities are given by (3), (4), (5) and (6), where w is determined by price competition between U_i and U_j on the intermediate market. Because U_i produces the intermediate good with a non-standard technology, U_j has an advantage on this rival. Indeed, whereas D_j can use the good produced by U_j without any cost other than the unit price v_j payed to U_j, it is not the case for the good produced by U_i. D_j has to adapt this good to the standard technology, with a cost of transformation of δ per unit. As a consequence, D_j compares v_j and $v_i + \delta$ when choosing its supplier. The integrated firm's upstream profit is thus[11] $wq_j(w)1_{v_i+\delta=w<v_j}$, whereas its downstream profit is $p_i(w)q_i(w)$, and U_j's (upstream) profit is $wq_j(w)1_{v_j=w\leqslant v_i+\delta}$. Bertrand competition thus leads to $w = v_j = \delta$, the non-integrated upstream firm supplying the non-integrated downstream firm at a unit price δ, at least as long as δ is inferior to the price v^* that U_j would charge as a monopolist, which we assume to hold in this and the following subsections. Any price $v_j > \delta$ would create an opportunity for F_i to capture D_j's demand and make profits by charging $v_i \in]\delta; v_j[$. Any price $v_j < \delta(< v^*)$ is suboptimal for U_j which can increase its profit by rising v_j without offering F_i the opportunity to capture D_j's demand.

As a consequence, firms' profits are given by

$$\Pi_{F_i}^{PI_i} = \left(\frac{\alpha}{2-\gamma} + \frac{\gamma\delta}{(2-\gamma)(2+\gamma)}\right)^2 - I - E \tag{11}$$

$$\Pi_{D_j}^{PI_i} = \left(\frac{\alpha}{2-\gamma} - \frac{2-\gamma^2}{4-\gamma^2}\delta\right)^2 \tag{12}$$

$$\Pi_{U_j}^{PI_i} = \delta\left(\frac{\alpha}{2-\gamma} - \frac{2-\gamma^2}{4-\gamma^2}\delta\right) \tag{13}$$

$$\Pi_{U_j}^{PI_i} + \Pi_{D_j}^{PI_i} = \left(\frac{\alpha}{2-\gamma} - \frac{2-\gamma^2}{4-\gamma^2}\delta\right)\left(\frac{\alpha}{2-\gamma} + \frac{2\delta}{4-\gamma^2}\right) \tag{14}$$

[11] We assume that D_j's demand is entirely addressed to the non-integrated firm when $v_i+\delta = v_j$. Considering a more general sharing rule would lead to the result that U_j charges a price equal to δ^-, infinitely close, but inferior to δ.

Recall that, if the integrated firm adopts the standard technology, it makes the profit $\pi_{F_i}^{PI_i}$ given by

$$\pi_{F_i}^{PI_i} = \left(\frac{\alpha}{2-\gamma}\right)^2 - I \tag{15}$$

The comparison of these two profits leads to

Lemma 1 *Under PI_i, assuming that $\delta < v^*$, F_i adopts a non-standard technology if and only if*

$$\delta > \frac{\alpha(2+\gamma)}{\gamma}\left[\sqrt{1+\left(\frac{2-\gamma}{\alpha}\right)^2 E} - 1\right] \tag{16}$$

Figure 1 shows the shape of the right side of (16).

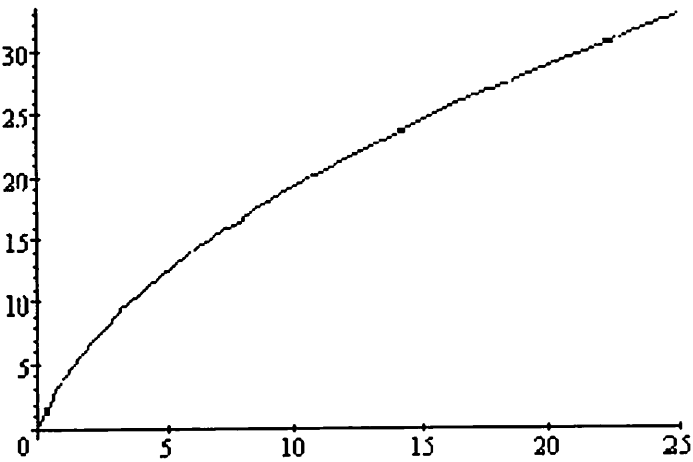

Figure 1 ($\alpha = 1$ and $\gamma = 0.5$)

In particular, for $E = 0$, the adoption of a non-standard technology is profitable if and only if $\delta > 0$. Indeed, this adoption is a costless rising rival's cost strategy. For $E > 0$, the adoption of a non-standard technology is costly and is optimal only if it generates a sufficient increase in gross profits.

If condition (16) is not satisfied, partial integration is not an equilibrium as integration has a cost I, but does not lead to an increase in the joint-profits of the merging firms. The structure characterized by the absence of vertical integration is the only equilibrium. Because we focus on the question of the emergence of vertical integration in equilibrium, we assume that condition (16) is satisfied. Foreclosure thus emerges under partial integration. Of course, the question of the emergence of partial integration in equilibrium remains.

4.2 Does partial integration emerge in equilibrium ?

In order to determine the Nash equilibrium of stage 1, we define f and g by

$$f(\alpha,\gamma,\delta) = \left(\frac{\alpha}{2-\gamma}\right)^2 \left[\left(1+\frac{\gamma\delta}{\alpha(2+\gamma)}\right)^2 - 1\right] \tag{18}$$

$$g(\alpha,\gamma,\delta) = \left(\frac{\alpha}{2-\gamma}\right)^2 \left[1-\left(1+\frac{2\delta}{\alpha(2+\gamma)}\right)\left(1-\frac{2-\gamma^2}{\alpha(2+\gamma)}\delta\right)\right] \tag{19}$$

One can easily check that f is just the difference between the profit of the integrated firm using a non-standard technology in a partial integration structure and the joint-profits of a pair of upstream-downstream firms under NI. It is thus the (gross) incentive for a pair of firms to deviate from the NI structure, integrate and adopt a non-standard technology. For this deviation to be profitable, f must be more than the cost of integrating and adopting a non-standard technology, that is, $I+E$. Note that condition (16) can be rewritten as $f(\alpha,\gamma,\delta) > E$.

Similarly, g is the (gross) incentive for non-integrated foreclosed firms to merge. It is the difference between the profit of an integrated firm in a FI structure and the joint-profits of a non-integrated pair of upstream-downstream firms facing an integrated competitor using a non-standard technology. It is thus the incentive for the $U_j - D_j$ pair of firms to deviate from the PI_i structure when condition (16) is satisfied. For this deviation to be profitable, g must be more than I, as the firm F_j will adopt the standard technology, which is less costly than non-standard technologies.

Proposition 1 *Assuming that δ is low – in the sense that it verifies the condition $\delta < v^*$ – and that condition (16) is satisfied, the structure of the industry in equilibrium is given by :*

PI with a non-standard technology if and only if $f(\alpha,\gamma,\delta) - E > I > g(a,\gamma,\delta)$,

NI if and only if $I \geqslant f(a,\gamma,\delta) - E$,

and

FI if and only if $I \leqslant g(\alpha,\gamma,\delta)$.

Proof. Writing the equilibrium conditions for the merger game leads to the proposition.

Note that the condition for partial integration with foreclosure to emerge in equilibrium implies (16), so that (16) can be omitted in the conditions for the emergence of partial integration as an equilibrium. However, condition (16) is an essential part of the conditions for the emergence of the other structures. Recall that if condition (16) is not satisfied, NI is the unique equilibrium of the game.

Note also that for any (I,E) at least one of the conditions in proposition 1 is satisfied, so that there is always an equilibrium in pure strategies for the merger game.

There remains the question of whether partial integration with foreclosure, when it is an equilibrium, is the unique equilibrium. Comparing the different conditions in proposition 1 leads to the following result.

Corollary 1 *If PI with foreclosure is an equilibrium, it is the unique equilibrium.*

Finally, we have to verify that the condition given in proposition 1 for the emergence of PI with foreclosure as an equilibrium of the game are met over at least a part of the range of the parameters. Note that as soon as $f(\alpha,\gamma,\delta) > g(\alpha,\gamma,\delta)$, there exists a range of values of I and E for which PI with a non-standard technology is an equilibrium. It is thus essential to compare f and g. It is straightforward to establish that $f(\alpha,\gamma,\delta) > g(\alpha,\gamma,\delta)$ if and only if[12]

$$\delta < \overline{w} = \frac{\alpha\gamma(2+\gamma)^2}{4-3\gamma^2} \tag{20}$$

Recall that we assumed the condition $\delta < v^*$ to be satisfied, so that, at this point of our analysis, we have shown that for any (α,γ,δ) such that $\delta < \overline{w}$ and $\delta < v^*$, there exists a range of values of I and E such that PI with a non-standard technology is an equilibrium of the game. It is then the unique equilibrium of the game.

4.3 High cost non-standard technologies

A complete resolution of the game requires us to examine the situation where $\delta \geqslant v^*$. Under this assumption, the intermediate price is given not by δ but by v^* in the "PI with a non-standard technology" structure. Up to this (essential) change, the analysis is similar to the previous one.

We calculate firms' profits by replacing w with the expression of v^* in (3), (4), (5) and (6) (see appendix A). The characterization of the industry structure depending on the parameters' values is presented in the following proposition.

Proposition 2 *Assuming that δ is high ($\delta \geqslant v^*$) and that $f^*(\alpha,\gamma) > E$, the structure of the industry in equilibrium is given by:*

PI with a non-standard technology if and only if $f^*(\alpha,\gamma) - E > I > g^*(\alpha,\gamma)$,

NI if and only if $I \geqslant f^*(\alpha,\gamma) - E$,

and

FI if and only if $I \leqslant g^*(\alpha,\gamma)$,

with $f^*(\alpha,\gamma) = f(\alpha,\gamma,v^*)$ and $g^*(\alpha,\gamma) = g(\alpha,\gamma,v^*)$.

The condition $f^*(\alpha,\gamma) > E$ ensures that an integrated firm facing non-integrated rivals finds it profitable to adopt a non-standard technology. It is just condition (16) with δ replaced by v^*. Note also that if partial integration is an equilibrium, it is the unique equilibrium of the game.

To complete the resolution, we have to compare $f^*(\alpha,\gamma)$ and $g^*(\alpha,\gamma)$. It is not a surprise to find that $f^*(\alpha,\gamma) > g^*(\alpha,\gamma)$ if and only if $v^* < \overline{w}$. Furthermore, numerical calculations allow us to establish that there exists a positive value $\widehat{\gamma}$ of γ comprised between 0.39 and 0.40 such that $v^* < \overline{w}$ if and only if $\gamma > \widehat{\gamma}$. This leads us to the conclusion that, for $\gamma > \widehat{\gamma}$, there exists a range of values of (I, E) such that PI with foreclosure is the unique equilibrium of the game. The price on the intermediate market is then equal to v^*. To the contrary, if $\gamma \leqslant \widehat{\gamma}$, there is not value of I and E such that partial integration is an equilibrium. These results confirm the intuition developed in section 3 that close substitutability of the goods offered on the final market is favorable to the emergence of partial integration and foreclosure.

12 As soon as $\delta \geqslant \overline{w}$, U_j can make a profitable and acceptable offer to D_j and a reactive merger occurs. Alternatively, D_j also can make a profitable and acceptable offer to U_j. See section 2.1.

4.4 Equilibrium industry structure

To sum up, partial integration with the adoption of a non-standard technology, in other words partial integration with foreclosure, is the unique equilibrium of the game defined in section 2 in the following three cases:

(i) $\gamma \leqslant \widehat{\gamma}$, $\delta < \overline{w}$ and $f(\alpha, \gamma, \delta) - E > I > g(\alpha, \gamma, \delta)$.

The price on the intermediate market is then equal to δ.

(ii) $\gamma > \widehat{\gamma}$, $\delta \geqslant v^*$ and $f^*(\alpha, \gamma) - E > I > g^*(\alpha, \gamma)$.

The price on the intermediate market is then equal to v^*.

(iii) $\gamma > \widehat{\gamma}$, $\delta < v^*$ and $f(\alpha, \gamma, \delta) - E > I > g(\alpha, \gamma, \delta)$.

The price on the intermediate market is then equal to δ.

In the three cases, prices and quantities on the final market are deduced from (3), (4), (5) and (6).

When $\gamma \leqslant \widehat{\gamma}$ and $\delta \geqslant \overline{w}$, both δ and v^* make a reactive merger profitable and vertical foreclosure cannot emerge in equilibrium.

No matter what value the differentiation parameter takes, there exists a range of values of δ such that if non-standard technologies are characterized by an adaptation cost within this range, partial vertical integration with adoption of a non-standard technology is the unique equilibrium, as long as I and E satisfy given conditions. Roughly speaking, E must be sufficiently low and I must be neither to low nor to high. Only the combination of a high adaptation cost and a low degree of substitutability between final goods can make an equilibrium with vertical foreclosure impossible, in the sense that no value of E and I supports this equilibrium.

5 Conclusion

In our model, the question whether integrated firms foreclose their non-integrated rivals is equivalent to the question whether they adopt a non-standard technology, that is, a technology that doesn't allow them to produce the intermediate good in its standard form so that, if they supply non-integrated downstream firms, the good must be adapted to the standard technology. In equilibrium, non-integrated firms using a non-standard technology don't supply non-integrated downstream firms. In other words, the adoption of a non-standard technology induces the foreclosure of downstream rivals. To the contrary, if integrated firms adopt the standard technology, no foreclosure occurs. The strategic effect of vertical integration is thus fully determined by the technological choice of vertically integrated firms. This idea is in accordance with the empirical facts presented in the article.

What is more, we show that partial integration with foreclosure occurs in equilibrium over a broad range of values of the substitutability parameter and the adaptation cost. Since vertical separation is, in this model, socially optimal, as vertical integration only can rise intermediate and final prices, our results are in favor of a strict control of vertical integration. However, it is quite risky to base recommendations for competition policy on a model that doesn't consider some important aspects of vertical integration, notably efficiency gains, but rather aims at pointing out the strategic aspects of vertical integration. However, since our model is analytically quite simple, we think that it can constitute a good basis for further developments and we are confident that the idea of a tight link between foreclosure and non-standard technologies could profitably be used in various theoretical settings.

6 Appendix A

It is straightforward to show that U_j's profit maximization in stage 3 leads to

$$v_j = v^* = \frac{\alpha(2+\gamma)}{2(2-\gamma^2)} \tag{21}$$

Calculating the profits leads to

$$\Pi_{F_i}^{PI_i} = \left(\frac{\alpha}{2-\gamma}\right)^2 \left(1 + \frac{\gamma}{2(2-\gamma^2)}\right)^2 - I - E \tag{22}$$

$$\Pi_{U_j}^{PI_i} = \left(\frac{\alpha}{2-\gamma}\right)^2 \left(\frac{4-\gamma^2}{4(2-\gamma^2)}\right) \tag{23}$$

$$\Pi_{D_j}^{PI_i} = \frac{1}{4}\left(\frac{\alpha}{2-\gamma}\right)^2 \tag{24}$$

If the integrated firm adopts the standard technology, it gets

$$\pi_{F_i}^{PI_i} = \left(\frac{\alpha}{2-\gamma}\right)^2 - I \tag{25}$$

References

Avenel, E., (1996), "Vertical vs. horizontal integration and pre-emptive merging : a comment", *Cahiers Eco & Maths* 96-53, Université de Paris I Panthéon-Sorbonne.

Colangelo, G., (1995), "Vertical vs. horizontal integration : pre-emptive merging", *The Journal of Industrial Organization*, **XLIII**, n° 3, pp. 323-337.

Gaudet, G. and N. Van Long, (1996), "Vertical integration, foreclosure and profits in the presence of double marginalization", *Journal of Economics & Management Strategy*, **5**, n° 3, pp. 409-432.

Hart, O. and J. Tirole, (1990), "Vertical integration and market foreclosure, *Brookings Papers on Economic Activity : Microeconomics*, pp. 205-276.

High Court of Australia, (1989), "Queensland Wire Industries Proprietary Limited v. The Broken Hill Proprietary Company Limited and another", 167 CLR 177 F.C. 89/004.

Ordover, J.A., G. Saloner and S.C. Salop, (1990), "Equilibrium vertical foreclosure", *American Economic Review*, **80**, pp. 127-142.

Reiffen, D., (1992), "Equilibrium vertical foreclosure : comment", *American Economic Review*, **82**, pp. 694-697.

Salinger, M.A., (1988), "Vertical mergers and market foreclosure", *Quarterly Journal of Economics*, **103**, pp. 345-356.

Schader, A., (1994), "Vertical mergers and market foreclosure : comment", Working Paper ECO n° 94/24, EUI, Florence, Italy.