Vertical Integration, Innovation and Foreclosure
Preliminary and incomplete - Please do not circulate

Marie-Laure Allain[1], Claire Chambolle[2] and Patrick Rey[3,4]

January 22, 2010

[1]Ecole Polytechnique (CNRS, Department of Economics, 91128 Palaiseau, France, email : marie-laure.allain@polytechnique.edu) and CREST.

[2]INRA (UR1303 ALISS, 94205 Ivry-sur-Seine, France) and Ecole Polytechnique (Department of Economics, 91128 Palaiseau, France, email: claire.chambolle@polytechnique.edu).

[3]Toulouse School of Economics (GREMAQ and IDEI).

[4]We thank Eric Avenel, Volker Nocke, Nicolas Schutz, Mike Whinston, Lucy White and participants at EARIE 2009, EEA 2009 and the 2008 ACE Conference in Budapest for their comments and useful references. We gratefully acknowledge support from the Ecole Polytechnique Business Economics Chair.

Abstract

This paper studies the potential effects of vertical integration on downstream firms' incentives to innovate. Interacting efficiently with a supplier may require some information exchanges, which raises the concern that sensitive information may then be disclosed to rivals. This may be particularly harmful in case of innovative projects, since it increases the risk of imitation. We show that vertical integration increases this threat of imitation, which de facto degrades the integrated supplier's ability to interact with unintegrated competitors. Vertical integration may thus lead to input foreclosure, thereby raising rivals' cost and limiting both upstream competition and downstream innovation. A similar concern of customer foreclosure arises in the case of downstream bottlenecks.

Jel Codes: L13, L41, L42.
Keywords: Vertical Integration, Foreclosure, Innovation, Imitation, Firewall.

1 Introduction

In this paper, we investigate whether vertical integration may trigger input foreclose through a risk of information leakage and imitation. Efficiency reasons may require firms to exchange sensitive information with their suppliers, which raises the concern that this information can then be disclosed to rivals. Vertical integration exacerbates this concern, since an integrated supplier can be more tempted to pass on such information to its downstream subsidiary. This issue is particularly serious in the case of innovative activities, as it creates a risk of imitation and thus tends to make the integrated supplier less reliable when dealing with downstream rivals. In other words, vertical integration may result in input foreclosure, not because the integrated firm will refuse to supply unaffiliated rivals but simply because it becomes less reliable.[1] Vertical integration therefore strengthens the market power of alternative suppliers, thus "raising rivals' costs" and impeding innovation.[2]

This issue is a growing concern for the European Commission, who mentions for example in its recent *Guidelines on the assessment of non horizontal mergers*: "The merged entity may, by vertically integrating, gain access to commercially sensitive information regarding the upstream or downstream activities of rivals. For instance, by becoming the supplier of a downstream competitor, a company may obtain critical information, which allows it to price less aggressively in the downstream market to the detriment of consumers. It may also put competitors at a competitive disadvantage, thereby dissuading them to enter or expand in the market."[3] This issue has also been raised in a number of merger cases.[4]

[1]While we focus here on input foreclosure, brand manufacturers voice similar concerns in connection with the development of private labels. As the promotional activities associated with the launch of new products generally require advance planning with the main retailers, manufacturers have expressed the fear that this may give these retailers an opportunity to reduce or even eliminate the lead time before the apparition of "me-too" private labels.

[2]For an early discussion of various "raising rivals' costs" strategies, see Krattenmaker and Salop (1986).

[3]*Guidelines on the assessment of non-horizontal mergers under the Council Regulation on the control of concentrations between undertakings* adopted by the European Commission on 18.10.2008 (O.J. 2008/C 265/07), at §78.

[4]Milliou (2004) mentions for example a number of US cases in R&D intensive sectors such as defense, pharmaceuticals, telecommunications, satellite and energy. In Europe, the issue was discussed in several merger cases. European cases include for example Boeing/Hughes (Case COMP/M.1879), Cendant/ Galileo (Case COMP/M.2510), Gess/Unison (Case COMP/M.2738) and EDP/ENL/GDP (Case COMP/M.3440).

A recent European example is the merger between TomTom and Tele Atlas.[5] TomTom manufactures portable navigation devices (or "PNDs"), whereas Tele Atlas is one of the two main providers of digital map databases for navigation in Europe and North America. In its decision, the European Commission states that "third parties have expressed concerns that certain categories of information considered confidential which they currently pass to Tele Atlas, for instance during technical consultations, could, after the merger, be shared with TomTom." This concern was based on the premise that "Tele Atlas's customers have to share information on their future competitive actions with their map supplier. [...] In a number of examples provided [...] by third parties, companies voluntarily passed information about their estimated future sales, product roadmaps and new features included in the latest version of their devices. They did this for four main reasons, firstly, to negotiate better prices, secondly, to incorporate existing features in new products, thirdly to encourage the map suppliers to develop new features, and finally, in order to ensure technical interoperability of new features with the core map and the software."[6] Third parties feared that "[a]ccess to information about the future behaviour of its downstream customers, would allow the merged firm to pre-empt any of their actions aimed at winning more customers (through better prices, innovative features, new business concepts, increased coverage of map databases). This would in turn reduce the incentive of TomTom's competitors to co-operate with Tele Atlas on pricing policy, innovation and new business concepts, all of which would require exchange of information. This would strengthen the market power of NAVTEQ, the only alternative map supplier, with regards to these PND operators and could lead to increased prices or less innovation".[7]

Our analysis supports these concerns. In a simple successive duopoly framework in which downstream firms must exchange sensitive information with their suppliers in

[5]Case No COMP/M.4854 - TOMTOM/TELE ATLAS, 14/05/2008.

[6]Commission decision at § 256.

[7]Commission decision at § 253. After a thorough examination the Commission finally concluded that "the confidentiality issues post-merger [were] unlikely to lead to a significant impediment of effective competition" in that case. The Commission assessed that a foreclosure strategy was unlikely to be profitable, since the price of the map database represents a very small part of the total production cost of a PND, and only part of a raise in the map price would be passed on to the PND's final price (see e.g. Decision at 216). The Commission felt moreover that the nature of the information exchanged between Tele Atlas and its customers limited the concerns and that the firewalls and non-disclosure agreements used by TeleAtlas could credibly be extended to the new situation. However, the detailed discussion of these issues confirms their potential relevance for the case.

order to implement innovation, we first show that vertical integration can indeed lead to foreclosure when it exacerbates a risk of imitation through information leakages. By making the supplier less "reliable", vertical integration forces the downstream competitor to share the value of its innovation with the other supplier; this discourages the rival' innovation efforts and expands the merging parties' market shares and profit at the expense of independent rivals. We then check that this insight is robust to various changes in the basic framework and that such strategic motive can make vertical integration attractive and hurt rivals even if these could in theory "fight back" and become vertically integrated themselves. Finally, we show that, through such foreclosure, vertical integration harms consumers and reduces total welfare.

We also discuss several reasons why an integrated firm may indeed be more likely to pass on sensitive information to its own subsidiary. Vertical integration may for example make it easier to transmit such information in a discreet way (or more difficult not to take advantage of this possibility). It may also be more efficient in coordinating the upstream and downstream efforts required for successful imitation. But, maybe more to the point, vertical integration moreover drastically alter the merged entity's incentives to protect customers' information; as a result, strategic motives do exacerbate the risk of imitation. If for example imitation requires to invest in reverse engineering technology, then an integrated firm may choose to make such an investment. An integrated firm has also less incentives to build effective firewalls or provide financial guarantees that the innovation will not be imitated. We first present these ideas in a static framework before showing, in a dynamic setting, how vertical integration affects the merged entity's incentives to build a reputation of reliability.

Our analysis is first related to the literature on market foreclosure and in particular to the seminal paper by Ordover, Saloner and Salop (1990), henceforth referred to as OSS. They argue that a vertical merger could be profitable as it allows the integrated firm to raise rivals' costs, by degrading their access to its own supplier and increasing in this way the market power of the alternative suppliers. Salinger (1988) has obtained the same result in a successive Cournot oligopoly framework where integrated firms are supposed to exit the intermediate market. As highlighted by Hart and Tirole (1990) or Reiffen (1992), both OSS and Salinger's analysis rely however on the assumption that the integrated firm could somehow commit to limit its supplies to downstream rivals, since otherwise it would have an incentive to keep competing with the alternative suppliers. By contrast, in our article the integrated supplier need not commit itself to refuse to deal with or limit its supplies to the rivals: by exacerbating the risk of information leakages, a vertical merger *de facto* degrades the perceived quality of the integrated supplier, which suffices to increase the market power of the alternative suppliers. Reiffen (1992) also mentions that the analysis of OSS relies on the assumption that suppliers can only charge linear prices on the intermediate market, otherwise the increased market power of the independent suppliers need not result into higher, inefficient marginal input prices. In our article, even if supply contracts are ex-post efficient (with cost-based marginal prices), increasing alternative suppliers' market power adversely affects unintegrated rivals' R&D incentives.[8]

Several papers have explored ways to dispense with the commitment assumption. For example, Gaudet and Long (1996) have shown in a successive Cournot oligopoly framework that an integrated firm can find profitable to buy some inputs in order to raise the input price, and thus its downstream rivals' cost. Choi and Yi (2000) revisit the commitment issue by showing that an integrated supplier could find profitable to offer an input specifically tailored to the needs of its downstream unit, rather than a generic input that could be sold to other firms as well.[9] Imperfect competition in the upstream market (combined with input linear prices) could also restore some foreclosure effects even in the absence of commitment not to supply.[10]

Our paper is also related to the literature on innovation and product imitation. Bhattacharya and Guriev (2006) investigate for example the link between the vertical market structure and the risk of imitation when information can be leaked. In a framework where a research unit bargains with two competitive development units, they compare the efficiency and R&D incentives generated by alternative modes of licensing: "open sale" (the usual form of patents) vs. "closed sale" and partial vertical integration (the licensor then holding a stake in the licensed firm's post-invention revenues). Although patenting is socially preferable, when the invention is highly profitable the parties may instead opt for a "closed sale", which limits the risk of leakage by reducing the incentives for secretly selling the information to downstream

[8]Note however that, as long as the integrated firm stops supplying the downstream rival, efficient contracting (e.g., two-part tariffs) among the independent firms need not result into cost-based marginal input prices, as the rivals could "dampen competition" by maintaining above-cost transfer prices – see Bonanno and Vickers (1988), Rey and Stiglitz (1995) and Shaffer (1991).

[9]See also Ma (1997).

[10]Hart and Tirole (1990), O'Brien and Shaffer (1992) and McAfee and Schwartz (1994) offer a different foreclosure rationale, in which vertical integration allows a bottleneck owner to exert more fully its market power over independent downstream firms. See Rey and Tirole (2007) for an overview of that literature.

competitors.

Several papers have more specifically studied the impact of firewalls who prohibit internal transfers of the proprietary information that a subsidiary may receive from third parties. For instance, Hughes and Kao (2001) consider a market structure where an integrated upstream firm, more efficient than its rivals, competes to supply a downstream competitor who is better informed about the demand. By supplying the downstream competitor, the integrated supplier learns private information on demand and shares it with its downstream subsidiary, which thus becomes more efficient. Since the integrated supplier has a cost advantage, it may nonetheless supply the informed downstream rival by setting a sufficiently attractive input price. Contrary to our paper, in that analysis a firewall would prevent the integrated supplier from offering a lower input price than its rivals and would thus raise the unintegrated competitor's cost and lower welfare.

Our paper is also close to Milliou (2004), who studies the impact of a firewall on downstream firms' R&D incentives; she considers the case of a pure bottleneck (the integrated supplier has full control of the intermediate market) and shows that a firewall enhances rivals' incentives to innovate but reduces the incentives of the integrated firm (in the case of complementary R&D paths) or enhances them (in the case of substitutes). In both cases, the integrated firm innovates more frequently in the absence of a firewall, however, due to the fact that it then benefits from the information flow (and the downstream rivals moreover face inefficient input prices). In contrast, we consider an R&D race in which competitors can turn to an alternative supplier, and indeed do so in the absence of a firewall; as a result, the integrated firm never actually benefits from any information flow and the adoption of a firewall would therefore not affect its behavior in the race for innovation (that is, its "best response" is not affected – the actual R&D effort however adapts to the change in rivals' R&D efforts). It follows that information flows always reduce the overall intensity of R&D.

The article is organized as follows. Section 2 develops a simple R&D model in which the risk of information leakages and imitation is treated as exogenous; we first use this model to show how vertical integration results in foreclosure, before providing several robustness checks and discussing welfare implications. Section 3 discusses various reasons, most notably strategic ones, why vertical integration can indeed increase the threat of imitation. Section 4 explores more formally a reputation argument in the context of a dynamic model. Section 5 concludes.

2 Foreclosure through the risk of imitation

We develop in this section a very simple model capturing the main intuitions. Our working assumption here is that, contrary to independent suppliers, an integrated supplier will always make use of any confidential information it can obtain from its customers in order to try and imitate their innovation. We show that this creates an incentive for vertical mergers motivated by input foreclosure and analyze the welfare consequences. As mentioned, we show in the next sections how this working assumption can be validated in various contexts where both integrated and independent suppliers choose whether to disclose customers' sensitive information.

2.1 Framework

Two upstream firms U_A and U_B supply a homogenous input to two downstream firms D_1 and D_2, which transform it into a final good and compete for customers. Unit costs are supposed to be constant and symmetric at both upstream and downstream levels, and are normalized to 0; we moreover assume that technical constraints impose single sourcing. Upstream competition for exclusive deals then leads the suppliers to offer efficient contracts, which boils down to supply any desired quantity in exchange for some lump-sum tariff T.[11]

Downstream firms may innovate, which increases the value of the final good they offer. If none or both innovate, the two downstream firms are equally efficient and Bertrand competition yields zero profit. When instead a single firm innovates, it benefits from a comparative advantage; it wins the market and obtains a profit $\Delta > 0$, while the other obtains again zero profits.[12] The payoff matrix is thus as follows, where I and N respectively denote "Innovation"and "No innovation":

Payoff matrix I

[11]Since suppliers compete here for exclusive deals, whether the contract terms are public or secret does not affect the analysis: in both instances, each supplier will have an incentive to propose an efficient contract, in which the marginal transfer price reflects the marginal cost (normalized here to 0).

[12]Suppose for example that a unit mass of consumers are each willing to buy one unit and that innovation increases consumers' reservation price r by Δ. When either none or both firms innovate, consumers have the same reservation price (r or $r+\Delta$) for the two varieties, and Bertrand competition drives down prices to cost (zero here). When instead one and only one firm innovates, asymmetric Bertrand yields a unique trembling-hand perfect equilibrium in which the innovator wins the market by charging a price Δ while the other offers to sell at cost.

$D_1 \backslash D_2$	I	N
I	$0, 0$	$\Delta, 0$
N	$0, \Delta$	$0, 0$

(1)

Each D_i decides how much to invest in innovation. More precisely, we suppose that D_i can innovate with probability ρ_i by investing an amount $C(\rho_i)$ – we will refer to ρ_i as D_i' s $R\&D$ effort. We will adopt the following regularity conditions:

Assumption A (unique, stable and interior innovation equilibrium). The cost function $C(.)$ is twice differentiable, convex and satisfies:

- **A(i)** $C''(.) > \Delta$;
- **A(ii)** $C'(0) = 0$;
- **A(iii)**$C'(1) > \Delta$.

$A(i)$ ensures that best responses are well behaved. $A(ii)$ and $A(iii)$ moreover imply that equilibrium probabilities of innovation strictly lie between 0 and 1.

In the absence of any vertical integration, the competition game is as follows:

- In stage 1, D_1 and D_2 simultaneously choose their $R\&D$ efforts and then innovate with probabilities ρ_1 and ρ_2; the success or failure of their innovation efforts is observed by all firms.
- In stage 2, U_A and U_B simultaneously offer lump-sum tariffs to each downstream firm; we will denote by T_{hi} the tariff offered by U_h to D_i (for $h = A, B$ and $i = 1, 2$); each D_i then chooses its supplier.

We also consider a variant of this game in which U_A is vertically integrated with D_1. Throughout this section, we assume that this vertical integration creates a risk for D_2 to see its innovation imitated by D_1 if it chooses U_A for supplier: in that case, with probability $\theta > 0$ the integrated firm successfully mimics the innovation (at no cost).

2.2 Vertical separation

Since the suppliers produce the same input with the same constant unit cost, in the second stage Bertrand-type competition yields $T_{Ai} = T_{Bi} = 0$. In the first stage, each D_i chooses its innovation effort, ρ_i, so as to maximize its expected profit given by

$$\Pi_i = \rho_i(1-\rho_j)\Delta - C(\rho_i). \tag{2}$$

It follows that the investment decisions are strategic substitutes:

$$\frac{\partial^2 \Pi_i}{\partial \rho_i \partial \rho_j} = -\Delta < 0. \tag{3}$$

Assumption A ensures that the best response, $\rho_i = R_i(\rho_j)$ which by construction is symmetric (that is, $R_i(.) = R_j(.)$) is uniquely characterized by:

$$C'(\rho_i) = (1-\rho_j)\Delta; \tag{4}$$

It moreover implies that the slope of the best response is lower than 1 (in absolute value):

$$0 > R'(\rho) = \frac{-\Delta}{C''(R(\rho))} > -1. \tag{5}$$

We have:[13]

Lemma 1 *In case of vertical separation, under Assumption A there exists a unique equilibrium, in which R&D efforts are symmetric and such that (where the superscript VS refers to Vertical Separation):*

$$\rho_1^{VS} = \rho_2^{VS} = \rho^* \in]0,1[. \tag{6}$$

Proof. *The convexity assumption $A(i)$, together with the boundary conditions $A(ii)$ and $A(iii)$, ensure that the best response to $\rho_j \in [0,1]$ is uniquely defined and given by $\rho_i = R(\rho_j)$, where $R(.)$ is characterized by (**??**). It moreover satisfies: (i) $R(1) = 0 < 1$, (ii) $R(0) > 0$, and (iii) $R'(\rho_j) < 0$. These properties imply that there is a unique value ρ^*, which moreover lies strictly between 0 and 1, such that $\rho^* = R(\rho^*)$. By construction, $\rho_1 = \rho_2 = \rho^*$ constitutes a symmetric equilibrium. Conversely, $R'(\rho) > -1$ implies that there is no other equilibrium.* ■

[13] We assume that fixed costs, if any, are small enough to ensure that expected profits are always positive (assuming $C(0) = 0$ would ensure that this is always the case) and thus that entry and exit considerations are not an issue.

2.3 Vertical integration

Suppose now that U_A and D_1 merge and gets the sum of its profits, and denote by $U_A - D_1$ the resulting integrated firm. In the second stage of the game, the two suppliers are again equally effective when either D_2 does not innovate, or both D_1 and D_2 innovate; in both cases, Bertrand-like competition among the suppliers leads them to offer cost-based tariffs to D_2. When instead D_2 is the sole innovator, dealing with the integrated suppliers exposes it to see its innovation imitated with probability θ: D_2's expected gross profit is again Δ if it buys from U_B but only $(1-\theta)\Delta$ if it buys from $U_A - D_1$. This gives U_B a comparative advantage over U_A, and in the resulting asymmetric competition U_B extracts from D_2 a rent corresponding to its comparative advantage: U_A offers to supply at cost ($T_{A2} = 0$), but U_B wins with $T_{B2} = \theta\Delta$.

In the first stage, D_2's expected profit is now given by

$$\Pi_2 = (1-\theta)(1-\rho_1)\rho_2\Delta - C(\rho_2), \tag{7}$$

whereas the integrated firm $U_A - D_1$'s expected profit is as before equal to:

$$\Pi_{A1} = \Pi_1 = \rho_1(1-\rho_2)\Delta - C(\rho_1). \tag{8}$$

Best responses are thus respectively given by $\rho_1 = R(\rho_2)$ and $\rho_2 = R_\theta(\rho_1)$, characterized by:

$$C'(\rho_1) = (1-\rho_2)\Delta, \tag{9}$$

as before, and:

$$C'(\rho_2) = (1-\theta)(1-\rho_1)\Delta. \tag{10}$$

$R_\theta(.)$ coincides with $R(.)$ for $\theta = 0$ and is identically equal to zero for $\theta = 1$. It moreover satisfies $R_\theta(1) = 0$ and, for $\rho_1 < 1$, it strictly decreases as θ increases from 0 to 1. As a result:

Lemma 2 *In case of vertical integration, under Assumption A there exists a unique equilibrium, in which R&D efforts are asymmetric whenever $\theta > 0$ and of the form (where the superscript VI refers to Vertical Integration):*

$$\rho_1^{VI} = \rho^+(\theta), \rho_2^{VI} = \rho^-(\theta), \tag{11}$$

where $\rho^+(0) = \rho^-(0) = \rho^*$, $\rho^-(1) = 0$, and $\rho^+(.)$ and $\rho^-(.)$ respectively increase and decrease as θ increases from 0 to 1.

Proof. *The convexity assumption $A(i)$, together with the boundary conditions $A(ii)$ and $A(iii)$, ensure that D_2's best response to $\rho_1 \in [0,1]$ is given by $\rho_2 = R_\theta(\rho_1)$ as characterized by (**??**). It moreover satisfies $R_\theta(1) = 0 < 1$ and, as long as $\theta < 1$, $R_\theta(0) > 0$ and:*

$$0 > R'_\theta(\rho) = \frac{-(1-\theta)\Delta}{C''(R_\theta(\rho))} > -1. \tag{12}$$

*The same reasoning as above then implies that there is a unique equilibrium, in which the R&D efforts satisfy $\rho^+(\theta) = R(\rho^-(\theta))$ and $\rho^-(\theta) = R_\theta(\rho^+(\theta))$. Clearly, $\rho^+(0) = \rho^-(0) = \rho^*$ since $R_0(.)$ coincides with $R(.)$, and (**??**) implies $\rho^-(1) = 0$. Moreover, replacing ρ_1 and ρ_2 by ρ^+ and ρ^- in (**??**) and (**??**), and differentiating these conditions with respect to ρ^+, ρ^- and θ yields:*

$$\frac{d\rho^+}{d\theta} = \frac{(1-\rho^+)\Delta^2}{C''(\rho^+)C''(\rho^-) - (1-\theta)\Delta^2} > 0, \tag{13}$$

since assumption $A(i)$ implies that the denominator is positive, whereas $A(iii)$ implies that the numerator, too, is positive (i.e., $\rho^+ < 1$); similarly:

$$\frac{d\rho^-}{d\theta} = \frac{-C''(\rho^+)(1-\rho^+)\Delta}{C''(\rho^+)C''(\rho^-) - (1-\theta)\Delta^2} < 0. \tag{14}$$

■

2.4 The foreclosure effect of vertical integration

Note first that vertical integration would have no impact here in the absence of R&D investments: with or without integration, both input providers would offer to supply at marginal cost. In contrast, when innovation matters, vertical integration often fosters imitation concerns. Our analysis shows that, indeed, when integration creates a risk of imitation, it de facto reduces the "quality" of the integrated firm as a supplier for the independent competitor, leaving it in the hands of the remaining, independent supplier. This "input foreclosure" enhances the independent supplier's market power, thereby raising the cost of supply for the downstream rival, who must share with the supplier the benefit of its *R&D* effort. It discourages the independent firm from investing in *R&D*, which in turn induces the integrated subsidiary to increase its own investment. The quality gap, and thus the foreclosure effect, increase with the risk of imitation. As long as this risk remains limited ($\theta < 1$), the integrated supplier still exerts a competitive pressure on the upstream market. As a result, the independent downstream competitor retains part of the value of its innovation and thus remains somewhat active on the innovation market ("partial foreclosure"). In contrast, when the risk of imitation is maximal ($\theta = 1$), When imitation is certain (($\theta = 1$)), the integrated supplier provides no value for the independent firm; the independent supplier actually would then extract the full benefit of any innovation by the independent firm, which thus no longer invests in R&D. The integrated firm then *de facto* monopolizes the innovation market segment (complete foreclosure).

Formally, a comparison of the investment levels with and without integration yields:

Proposition 3 *Compared with the case of vertical separation, a vertical merger between U_A and D_1 replicates the effect of input foreclosure:*

(i) it leads the independent firm D_2 to invest less, and the integrated subsidiary to invest more in innovation – and all the more so as the probability of imitation, θ, increases: when vertical integration triggers imitation with certainty ($\theta = 1$), the integrated firm monopolizes the innovation market.

(ii) it increases the joint profit of the merging parties, U_A and D_1, at the expense of the downstream independent rival D_2; while the independent supplier U_B benefits from its enhanced market power over D_2, the joint profit of the independent firms also decreases.

Proof. *Part (i) follows from the fact that $\rho^-(\theta)$ and $\rho^+(\theta)$ respectively decrease and increase as θ increases, and that they both coincide with ρ^* for $\theta = 0$, whereas $\rho^- = 0$ for $\theta = 1$. As for part (ii), it suffices to note that $\rho^-(\theta) < \rho^* < \rho^+(\theta)$ implies that the equilibrium profits satisfy:*

$$\begin{aligned} \Pi_{A1}^{VI} &= \max_{\rho} \rho \left(1 - \rho^-\right) \Delta - C(\rho) \\ &> \max_{\rho} \rho (1 - \rho^*) \Delta - C(\rho) = \Pi_1^{VS} = \Pi_A^{VS} + \Pi_1^{VS}, \\ \Pi_2^{VI} &= \max_{\rho} \rho \left(1 - \rho^+\right) \Delta - C(\rho) \\ &< \max_{\rho} \rho (1 - \rho^*) \Delta - C(\rho) = \Pi_2^{VS}; \end{aligned}$$

in addition:

$$\begin{aligned} \Pi_B^{VI} + \Pi_2^{VI} &= \rho^- \left(1 - \rho^+\right) \Delta - C\left(\rho^-\right) \\ &< \max_{\rho} \rho \left(1 - \rho^+\right) \Delta - C(\rho) \\ &< \max_{\rho} \rho (1 - \rho^*) \Delta - C(\rho) = \Pi_2^{VS} = \Pi_B^{VS} + \Pi_2^{VS}, \end{aligned}$$

where the first inequality stems from the fact that ρ^- is chosen by D_2 so as to satisfy its own profit rather than the joint profit of the independent firms. ■

Note that imitation never occurs in equilibrium, since the independent downstream competitor always ends up dealing with the independent supplier. Yet, the threat of imitation suffices to increase the independent supplier's market power at the expense of the independent downstream firm's who reduces its innovation effort.

This input foreclosure effect benefits the integrated firm $(U_A - D_1)$ who faces a less aggressive aggressive rival. Due to strategic substitution, the integrated firm moreover responds by increasing its investments which not only further degrades D_2's profit but also degrades the joint profits of the independent firms.[14]

2.5 Robustness

This analysis is robust to various changes in the modeling assumptions.

Information leakages. The analysis still applies for example when information flows already exist in the absence of any merger, as long as vertical integration increases these flows and the resulting probability of imitation, e.g., from $\underline{\theta}$ to $\overline{\theta}$. The distortion term $\theta\Delta$ then simply becomes $\left(\overline{\theta} - \underline{\theta}\right)\Delta$.

Bilateral bargaining power. The same logic applies when downstream firms have significant bargaining power in the bilateral negotiations with their suppliers, as long as suppliers obtain a positive share of the specific gains generated by the relationship. Suppose for example that suppliers obtain a share $\lambda < 1$ of these specific gains from trade. This does not affect the outcome in case of vertical separation: since both suppliers are equally effective in that case, there is no specific gain to be shared and downstream firms thus still obtain the full benefit of their innovation; R&D efforts are therefore given by $\rho_1^{VS} = \rho_2^{VS} = \rho^*$. In contrast, in case of vertical integration the independent supplier obtains a share λ of its comparative advantage over the integrated rival whenever D_2 is the only innovator (that is, $T_{B2} = \lambda\theta\Delta$ in that case);

[14]The joint profit of U_B and D_2 is furthermore impaired by coordination failure in D_2's investment decision (that is, $\rho^- < R\left(\rho^+\right)$). Also, while U_B always benefits here from foreclosure (since it obtains no profit in the benchmark case of vertical separation), in more general contexts, foreclosure may have an ambiguous impact on U_B, who obtains a larger share of a smaller pie. In contrast, in the OSS foreclosure scenario, the profit of the independent suppliers as well as the joint profit of the independent rivals increase, since the integrated firm raises its price in the downstream market.

D_2's expected profit thus becomes:

$$\Pi_2 = (1 - \lambda\theta)(1 - \rho_1)\rho_2\Delta - C(\rho_2). \tag{15}$$

The same analysis then applies, replacing the probability θ with the "adjusted probability" $\lambda\theta$, which now depends on the relative bargaining power of the supplier as well as on the risk of imitation. As long as $\lambda > 0$, innovation efforts are again distorted compared with the case of vertical separation.

Imperfect imitation. In practice, an imitator may not be as effective a competitor as a genuine innovator; the imitator may for example lag behind the innovator, who can moreover take steps to protect further its comparative advantage. Yet, the analysis applies as long as imitation reduces the value of the innovation by $L < \Delta$, say. In case of vertical integration, whenever D_2 is the sole innovator the independent supplier can still charge a positive markup reflecting its comparative advantage, $T_{B2} = \theta L > 0$.

Imperfect competition in the downstream market. When downstream competition is limited, due e.g. to product differentiation, capacity constraints, or competition in quantities rather than in prices, imitation may not dissipate profits entirely but leave instead a profit, say δ, to each firm; the payoff matrix thus becomes:[15]

Payoff matrix II

$D_1 \backslash D_2$	I	N
I	δ, δ	$\Delta, 0$
N	$0, \Delta$	$0, 0$

(16)

As long as imitation reduces an innovator's profits (that is, as long as $\delta < \Delta$), the integrated supplier still appears as an inferior, less reliable supplier when D_2 is the sole innovator. However, the integrated supplier is now willing to offer D_2 a discount (up to $T_{A2} = -\theta\delta$), reflecting the gain that it could derive from imitating the innovation. Offering such discount exerts a tougher pressure on U_B; it but still leaves U_B with

[15] Suppose that the innovation allows a downstream firm to create a new good or to address a new market segment. If only one firm innovates, it can obtain the corresponding monopoly profit, π^M; if instead both firms innovate, then they share a lower duopoly profit $\pi^D < \pi^M$. We then have $\Delta = \pi^M$ and $\delta = \Pi^d/2$. For example, in a Cournot duopoly with linear demand $P(Q) = d - Q$ in which innovation would reduce the unit cost c from d (so that the market is barely viable) to 0, a firm that does not innovate obtains zero profit, while the monopoly profit is $\pi^M = (d/2)^2$ and the duopoly profit is $\pi^C = (d/3)^3 < \pi^M$.

some market power over D_2 as long as imitation reduces the industry profits (that is, $\Delta > 2\delta$),[16] since the maximal discount that U_A can offer, equal to $\theta\delta$, cannot compensate D_2 for the associated loss of profit, $\theta(\Delta - \delta)$. U_B thus still wins the competition for D_2 by offering a tariff above cost, $T_{B2} = \theta(\Delta - 2\delta) > 0$.

Differentiated suppliers. The above reasoning carries over to the case where the upstream firms produce imperfect substitutes, as long as vertical integration renders the integrated supplier less reliable for the independent downstream firms. Imagine that each of the downstream firm has a favorite supplier: D_1 (resp. D_2) obtains an additional surplus γ when buying from U_A (resp. U_B). If U_A and D_1 vertically integrate, the integrated supplier is therefore even less attractive when D_2 is the sole innovator. In case of imperfect competition downstream, the integrated firm would be ready to offer D_2 a subsidy $T_{A2} = -\theta\delta$, reflecting the expected gain from imitation, but U_B would still win the competition for D_2 with a tariff above cost, $T_{B2} = \theta(\Delta + \gamma - 2\delta) > 0$. Note that this would also be the case if U_A were D_2's favorite supplier, as long as this advantage does not offset reliability concerns (i.e, as long as $\gamma < \Delta - 2\delta$). The strategic foreclosure effect is however stronger when a downstream firm merges with its own favorite supplier.

Number of competitors. It should be clear that the analysis does not rely critically on the restriction to duopolies. If for example there were additional stand-alone downstream firms, vertical integration would enhance the market power of the independent supplier over these other firms as well, thus discouraging their *R&D* efforts to the benefit of the integrated firm. Likewise, the argument still applies when there are more than two suppliers: as long as upstream competition remains imperfect, degrading the perceived quality of an integrated supplier enhances the market power of the other suppliers over the independent downstream firms.

Timing of negotiations. We assumed so far that negotiations take place only once an innovation materializes. This makes sense, for example, when it is difficult to specify ex ante the exact nature of the innovation. The same analysis however applies when negotiations take place earlier on, as long as *R&D* efforts are observed beforehand.[17] In case of vertical separation the two suppliers then offer again cost-based tariffs, whereas with partial integration, the independent supplier imposes a tariff reflecting its expected comparative advantage over the integrated supplier, $T_{B2} =$

[16] Indeed, in the example described in the previous footnote, $\Delta = \pi^M > 2\delta = \pi^D$.

[17] If instead the investment were decided after the negotiations with the suppliers, no foreclosure effect would arise.

$\theta(1-\rho_1)\rho_2\Delta$, which has exactly the same impact on D_2's incentives to invest in $R\&D$.

Customer foreclosure. Finally, the analysis can be readily transposed to the case where upstream manufacturers invest in $R\&D$ efforts and need to exchange information with their distributors in order to launch new products. Thus, suppose for example that: (i) two upstream firms U_A and U_B create a new product with probabilities ρ_A and ρ_B by investing $C(\rho_A)$ and $C(\rho_B)$; (ii) when an upstream firm innovates, it can choose either D_1 or D_2 to launch and distribute the new product; and (iii) a successful launch requires early communication of confidential information about the characteristics and new features of the product, which facilitates the development of "me-too" substitutes. Concerns about information leaks then militate for relying on a single distributor, in which case the situation is essentially the same as the one studied above. Consider for example the following competition game, which mirrors the previous one:

- In stage 1, U_A and U_B simultaneously choose their R&D efforts and then innovate with probabilities ρ_A and ρ_B; the success or failure of their innovation efforts is observed by all firms.
- In stage 2, D_1 and D_2 simultaneously offer lump-sum tariffs to each manufacturer, who then chooses its distributor.

Adopting similar cost and profit conditions as above, this competition game yields again a symmetric outcome of the form $\rho_A = \rho_B = \rho^*$ in case of vertical separation, and an asymmetric outcome reflecting a foreclosure effect, of the form $\rho_A = \rho^+ > \rho_B = \rho^-$, when for example U_A merges with D_1. As a result, vertical integration increases the profit of the merging parties, at the expense here of the independent manufacturer.

2.6 Rivals' counter-fighting strategies

Since input foreclosure increases the profit of the merging firms at the expense of their rivals, it may encourage these rivals to merge as well. Indeed, the situation with two vertical mergers is similar to the initial, no-merger situation, since there is again no risk of imitation: the two integrated suppliers supply at cost their subsidiaries, which will thus invest $\rho_1 = \rho_2 = \rho^*$. Since each integrated firm then obtains Π^*, in the absence of any specific cost of integration the rivals would have an incentive to merge in response to a first vertical merger.

Note however that the two situations (with zero or two mergers) would be different if there were any remaining independent downstream competitor. In case of vertical separation, the two suppliers would then sell at cost to all downstream firms, resulting in a level-playing field competition in the downstream market. To be sure, a first vertical merger between, say, U_A and D_1 , would encourage a second merger between U_B and, say, D_2. In the resulting situation, the two suppliers would again sell at cost to all downstream firms but would now be less reliable for the independent ones; as a result, downstream competition would be biased in favour of the integrated firms, who would still enjoy a reliable access to the upstream market. Thus, the integration wave would confer a strategic advantage to the merging parties to the detriment of the independent rivals, who would again decrease their $R\&D$ efforts.

But even in our duopoly model, a first merger can be profitable when integration is costly, in such a way that the initial merger does not lead the rivals to integrate; letting K denote the cost of integration, this will be the case when:

$$\underline{K} \equiv \Pi^* - \left(\Pi_B^{VI} + \Pi_2^{VI}\right) < K < \overline{K} \equiv \Pi_{A1}^{VI} - \Pi^*. \tag{17}$$

The interval $[\underline{K}, \overline{K}]$ is non empty when $\Pi_{A1}^{VI} + \Pi_B^{VI} + \Pi_2^{VI} > 2\Pi^*$, i.e., when a merger raises total industry profit. We thus obtain the following proposition:

Proposition 4 *When partial vertical integration decreases total industry profit, a vertical merger either is unprofitable or triggers a counter-merger that eliminates any strategic advantage for the first merging firms. In contrast, when partial integration raises total industry profit,* $\underline{K} < \overline{K}$ *and whenever integration involves a cost* $K \in \left[\underline{K}, \overline{K}\right]$*, the remaining independent firms have no incentive to merge in response to a first vertical merger; as a result, the first merger creates a foreclosure effect that confers a strategic advantage to the merging firms, at the expense of the independent downstream rival.*

The scope for counter-fighting strategies thus depends on the impact of partial integration on industry profits, which itself is ambiguous. To see this, consider the following standard quadratic specification for the R&D costs:

Assumption B

$$C(\rho) = \frac{k}{2}\rho^2.$$

Assumption A then boils down to:

$$\eta \equiv \frac{k}{\Delta} > 1.$$

We have:

Proposition 5 *Under assumption B, partial vertical integration, raises total industry profit when and only when innovation is not too costly ($\eta < \check{\eta} \equiv 1 + \sqrt{2}$) or the risk of imitation is not too large ($\theta < \check{\theta}(\eta)$, where $\check{\theta}(\eta) < 1$ for $\eta > \check{\eta}$).*

Proof. Straightforward computations yield:

- In case of vertical separation:

$$\rho_1^{VS} = \rho_2^{VS} = \rho^* = \frac{1}{1+\eta}, \tag{18}$$

$$\Pi_1^{VS} = \Pi_2^{VS} = \Pi^* = \frac{k}{2}\left(\frac{1}{1+\eta}\right)^2. \tag{19}$$

- In case of vertical integration between U_A and D_1:

$$\rho_1^{VS} = \rho^+ = \frac{\eta - (1-\theta)}{\eta^2 - (1-\theta)}, \rho_2^{VS} = \rho^- = \frac{(1-\theta)(\eta-1)}{\eta^2 - (1-\theta)}, \tag{20}$$

$$\Pi_{A1}^{VI} = \frac{k(\rho^+)^2}{2} = \frac{k}{2}\left(\frac{\eta - (1-\theta)}{\eta^2 - (1-\theta)}\right)^2, \Pi_B^{VI} + \Pi_2^{VI} = \frac{k}{2}\left(1-\theta^2\right)\left(\frac{\eta - 1}{\eta^2 - (1-\theta)}\right)^2.$$

It can then be checked that partial vertical integration always increases total industry profit when $\eta < \check{\eta} = 1 + \sqrt{2}$; when instead $\eta \geq \check{\eta}$, vertical integration increases total industry profit if and only if $\theta < \check{\theta}(\eta) \equiv \frac{2(\eta-1)^2(\eta+1)}{(\eta^2-3)\eta^2 - 2(\eta-1)}$, where $\check{\theta}(\eta) \in [0,1]$ and $\check{\theta}'(\eta) < 0$. ■

To understand the impact of vertical integration on total industry profit, it is useful to consider what would be the optimal R&D efforts for the downstream firms if they could coordinate their investment decisions (but still compete in prices).[18] When innovation efforts are inexpensive (namely, $\eta < 2$), the firms would actually find it optimal to have *one* firm (and only one) invest $\frac{1}{\eta}\left(> \frac{1}{2}\right)$, so as to avoid the competition that arises when both firms innovate. If instead innovation efforts are expensive ($\eta \geq 2$), the decreasing returns to scale make it optimal to have both firms invest $\frac{1}{\eta+2} < \rho^*$. Compared with this benchmark, in the absence of integration, downstream competition leads the firms to overinvest in innovation, since each firm neglects the negative externality that its investment exerts on the rival's expected profit. Consider now the case of partial integration and for the sake of exposition, let

[18] These R&D efforts thus maximize a joint profit equal to: $(\rho_1(1-\rho_2)+\rho_2(1-\rho_1))\Delta - k\rho_1^2/2 - k\rho_2^2/2$.

us focus on the polar case of complete foreclosure $\theta = 1$. Vertical integration thus de facto implements the integrated industry optimum when $\eta < 2$. When instead innovation efforts are expensive, i.e. η is large, the resulting asymmetric investment levels and the underlying decreasing returns to scale reduce industry joint profits. From proposition **??**, a vertical merger then generates a profitable foreclosure effect without triggering a counter-merger.

2.7 Welfare analysis

We first study here the impact of vertical integration on investment levels and on the probability of innovation,

$$\varrho \equiv 1 - (1 - \rho_1)(1 - \rho_2) = \rho_1 + \rho_2 - \rho_1\rho_2,$$

before considering its impact on consumer surplus and total welfare.

Proposition 6 *Partial vertical integration reduces total investments; it also reduces the probability of innovation when θ is not too large, but can increase it for larger values of θ. For example, under Assumption B it decreases the probability of innovation if and only if innovation is very costly ($\eta \geq \hat{\eta}$, where $\eta > 1$) or when the risk of imitation is not too large ($\theta < \hat{\theta}(\eta)$, where $\hat{\theta}(\eta) < 1$ for $\eta < \hat{\eta}$).*

Proof. By construction, the probability of innovation is $\varrho(\theta) = \rho^+(\theta) + \rho^-(\theta) - \rho^+(\theta)\rho^-(\theta)$ in the case of partial integration and $\varrho^* = \varrho(0)$ in the case of separation. Under $A(i)$, total investment decreases when θ increases:

$$\frac{d(\rho^- + \rho^+)}{d\theta} = \frac{(1 - \rho^+)(\Delta - C''(\rho^+))\Delta}{C''(\rho^+)C''(\rho^-) - (1 - \theta)\Delta^2} < 0.$$

The probability that both firms innovate also decreases with θ:

$$\frac{d(\rho^- \rho^+)}{d\theta} = \frac{(1 - \rho^+)(\rho^- \Delta - C''(\rho^+)\rho^+)\Delta}{C''(\rho^+)C''(\rho^-) - (1 - \theta)\Delta^2} < 0.$$

The overall effect on the probability of innovation is therefore:

$$\varrho'(\theta) = \frac{(1 - \rho^+)((1 - \rho^-)\Delta - (1 - \rho^+)C''(\rho^+))\Delta}{C''(\rho^+)C''(\rho^-) - (1 - \theta)\Delta^2}.$$

This expression is negative for small values of θ since, for $\theta = 0$, $\rho^+ = \rho^- = \rho^*$ and thus: $\varrho'(0) = -\frac{(1-\rho^*)^2\Delta}{C''(\rho^*)+\Delta} < 0$; it then follows that, for these values of θ, partial integration decreases the probability of innovation (that is, $\varrho(\theta) < \varrho^* = \varrho(0)$).

For larger values of θ, however, the impact may be positive. Indeed, under Assumption B straightforward computations yield $\varrho^{'}(\theta) < 0$ as long as $\theta < \bar{\theta}(\eta) \equiv (\eta - 1)^2$, where $\bar{\theta}(\eta)$ is positive and increases with η in the relevant range $\eta > 1$; in contrast, $\varrho^{'}(\theta) > 0$ when $\theta > \bar{\theta}(\eta)$. As a result, partial integration reduces the overall probability of innovation (i.e., $\varrho(\theta) < \varrho(1)$) if and only if $\theta < \hat{\theta}(\eta) \equiv (\eta^2 - 1)(\eta - 1)$, where $\hat{\theta}(\eta)$ is strictly higher than $\bar{\theta}(\eta)$, $\hat{\theta}'(\eta)$ 0, and $\hat{\theta}(\eta) < 1$ as long as $\eta < \hat{\eta} = \frac{1+\sqrt{5}}{2}$. ■

An increase in the risk of imitation θ reduces the investment of the independent firm. Under $A(i)$, this direct negative effect always dominates the indirect positive effect on the investments of its rival; therefore total investment decreases. As for the effect on the probability of innovation, the impact of an increase in θ can be written as $\varrho^{'}(\theta) = (1 - \rho_1)\rho_2^{'}(\theta) + (1 - \rho_2)\rho_1^{'}(\theta)$, that is a change in innovation of one firm only affects the probability of innovation when the other firm fails to innovate. When the two firms invest to a similar extent (e.g., when θ is close to zero), the effect of an increase in θ on the probability of innovation is similar to the impact on the sum of investments. When instead, the vertically integrated firm invests much more in *R&D* than its independent rival, the effect of an increase in θ on the probability of innovation is mainly driven by its positive (indirect) effect on the integrated firm's effort.

In order to study the impact of vertical integration on consumers and welfare, let us follow the interpretation presented in footnote **??**: the firms produce initially an homogeneous good and innovation uniformly increases consumers' willingness to pay by Δ; consumers then obtain the full benefit of innovation when both firms innovate, but none of it when only one firm innovates. The (expected) consumer surplus S and total welfare W are then:

$$
\begin{aligned}
S &\equiv \rho_1\rho_2\Delta, \\
W &\equiv (\rho_1 + \rho_2 - \rho_1\rho_2)\Delta - C(\rho_1) - C(\rho_2).
\end{aligned}
$$

As shown in the proof of proposition **??**, vertical integration always reduces the probability that both firms innovate simultaneously, and thus unambiguously reduces expected consumer surplus. For the quadratic cost specification, it can further be checked that vertical integration reduces total welfare:

Proposition 7 *Suppose that firms produce initially a homogenous good and that innovation uniformly increases consumers' willingness to pay by Δ; then vertical integration:*

(i) always lowers consumer surplus.

(ii) under assumption B, always lowers total welfare.

Proof. Part (i) follows from the proof of proposition **??**, which shows that the probability that both firms innovate under partial integration decreases with θ and coincides for $\theta = 0$ with that obtained with vertical separation.

For part (ii), it suffices to note that vertical integration has no impact on innovation and welfare when $\theta = 0$ and that $W^{VI}(\theta) = (\rho^+ + \rho^- - \rho^-\rho^+)\Delta - k\frac{\rho^{+2}}{2} - k\frac{\rho^{-2}}{2}$ satisfies $\frac{dW^{VI}}{d\theta} = -\frac{(\eta-1)^3\eta(\eta-1+\theta)}{(\eta^2+\theta-1)^3} < 0$. ■

3 Does vertical integration raise the threat of imitation?

To reflect concerns voiced in certain markets, in the previous section we postulated that vertical integration exogenously creates a risk of information leakage and imitation. We now relax this assumption and allow suppliers, integrated or not, to decide whether to exploit their customers' information. Indeed, since such information would be valuable to downstream competitors, even independent suppliers may choose to "sell"[19] it to (some of) these competitors. As we will show, vertical integration drastically affects the ability of the firms, as well as their incentives, to do so.

First, vertical integration may facilitate information flows between the upstream and downstream units of the integrated firm – and may make it easier to keep such information flows secret. For example, the merged entity may wish to integrate their IT networks, which may not only facilitate information exchanges but also make it more difficult to maintain credible firewalls. As a result, an integrated supplier may be unable to commit itself not to disclose any business secret even when an independent supplier could achieve that.

Second, an integrated firm may be more successful in coordinating the upstream and downstream efforts required to exploit rivals' information. Suppose for example that the probability of successful imitation is equal to $\theta_U\theta_D$, where θ_U and θ_D are unobservable and respectively controlled by the upstream and downstream firms. Suppose further that each θ_i can take two values, $\underline{\theta}$ and $\overline{\theta} > \underline{\theta}$, and that opting for the low value $\underline{\theta}$ yields a private, non-transferable benefit, whereas successful imitation

[19] The "price" can take several forms: a higher input price, the extension of the customer's contract, the introduction of exclusive dealing or quota provisions, and so forth.

gives the downstream firm a monetary benefit. We show in Appendix **??** that it is easier for an integrated firm to align upstream and downstream incentives in order to achieve the highest probability of successful imitation, $\overline{\theta\theta}$. In other words, vertical integration can indeed increase the likelihood of imitation.

Third, while independent suppliers have incentives to maintain a good reputation, the incentives of integrated suppliers are drastically altered by strategic considerations, since entertaining the fear of information leakage and imitation yields foreclosure benefits. To see this, in what follows we compare the outcome of partial vertical integration to the outcome that prevails in a vertically separated industry, and consider three ways in which an integrated supplier can increase this fear of information leakage and imitation: it may (i) invest in costly reverse-engineering technology; (ii) refuse to compensate downstream firms in case of information leakage; and (iii) refuse to set up firewalls.

We present the above arguments in a simple way here, by assuming that in a preliminary stage, suppliers publicly choose to be "reliable" or not. We thus consider the following type of game:

- In stage 0, both suppliers, vertically integrated or not, decide whether to be reliable.

- In stage 1, D_1 and D_2 simultaneously choose their $R\&D$ efforts and then innovate with probabilities ρ_1 and ρ_2; the success or failure of their innovation efforts is observed by all firms.

- In stage 2, U_A and U_B simultaneously offer lump-sum tariffs to each downstream firm; we will denote by T_{hi} the tariff offered by U_h to D_i (for $h = A, B$ and $i = 1, 2$); each D_i then chooses its supplier. Finally, unreliable suppliers have the opportunity to sell their customers' information to unsuccessful downstream rivals, through a take-it-or-leave-it offer, in which case the downstream rival is able to duplicate the imitation (i.e., $\theta = 1$).

In the next section, we dispense with the commitment assumption (i.e., stage 0) and show that the same line of arguments holds in a reputation framework.

3.1 Reverse engineering

In order to benefit strategically from "unreliability", a supplier may make irreversible decisions facilitating imitation, for example by investing in reverse engineering capability. To capture this possibility, suppose that, in stage 0, each supplier must decide whether to invest publicly in such reverse engineering technology: the technology costs F but then allows to duplicate any innovation with probability 1. To ensure that duplication is valuable, we will adopt the payoff matrix II, where $\delta < \Delta/2$ is the gain of imitation.

By construction, suppliers who do not invest in reverse engineering capability cannot disclose their customers' information. Consider now the case of an unreliable supplier who did invest in such capability. If the supplier is integrated, it will never provide internal information to its independent rival, since the gain from doing so cannot exceed δ, and thus never compensates for the resulting loss in downstream profit, $\Delta - \delta$. In contrast, any supplier (integrated or not) would have an incentive to sell the information from an unaffiliated customer since doing so yields a gain δ.

An *independent* supplier will however never invest in reverse engineering technology, as this would put its business at risk. Suppose for example that the rival does not invest in reverse engineering. Not investing then leads to symmetric competition and zero profit, whereas investing would cost F without bringing any benefit, since the rival would win the competition for customers. Suppose instead that the rival invests, and consider first the competition for independent customers. Investing as well leads to symmetric competition between equally unreliable suppliers, resulting in a net loss F, whereas not investing saves that cost and moreover confers a comparative advantage. As for an integrated customer, investing as well is costly and yields a comparative disadvantage whereas not investing yields symmetric competition.

Therefore, if both suppliers are vertically separated, the only equilibrium is such that no one invests in reverse engineering. By contrast, an integrated firm might find it profitable to invest in reverse engineering, in order to benefit from the resulting foreclosure effect:

Proposition 8 *Independent suppliers never invest in reverse engineering. In contrast, as long as the technology is not too costly, an integrated supplier invests in reverse engineering in order to benefit from input foreclosure.*

Proof. See Appendix **??**. ■

3.2 Providing guarantees

Suppliers could provide guarantees against the risk of information leakages, e.g. by offering compensations in case of imitation. But since an integrated firm strategically benefits from being "unreliable", it may choose not to offer such compensation. To see this, consider the same situation as above except that, in stage 0, the suppliers no longer need to invest in reverse engineering but can instead offer a compensation in case of imitation, which is large enough to deter suppliers from passing on the information received from its customers.[20] Thus, contrary to the previous section, being reliable or not involves no actual cost: suppliers already have the technology enabling them to use their customers' information (by default, they are thus unreliable), but offering a compensation allows them to be reliable at no cost (as it deters suppliers from exploiting their customers' information, no compensation will ever be paid).

As for downstream profits, to avoid equilibrium multiplicity issues we introduce some upstream differentiation along the lines discussed in section **??**: in case of innovation, D_1 (resp. D_2) obtains a small additional surplus γ when dealing with U_A (resp. U_B). We have:

Proposition 9 *As long as the benefit from differentiation is not too large, it is a dominant strategy for any independent supplier to guarantee compensation in case of imitation. In contrast, in case of partial integration the integrated supplier offers no guarantee, so as to benefit from strategic foreclosure.*

Proof. See Appendix **??**. ■

Consider first the case where an integrated firm, $U_A - D_1$, say, competes against a reliable rival, U_B. The integrated firm then supplies its own subsidiary (and protect its innovation from imitation) but never wins the competition for the independent downstream firm, who always favors the rival. Therefore, whether or not it offers compensating guarantees, $U_A - D_1$'s expected profit is given by:

$$\rho_1 \left((1 - \rho_2)(\Delta + \gamma) + \rho_2(\delta + \gamma) \right) - C\left(\rho_1\right).$$

However, not providing guarantees increases U_B's market power over D_2, and in particular allows U_B to keep a larger share of the value of D_2's innovation; this reduces as before D_2's innovation effort, and this foreclosure effect benefits the integrated firm, which faces a weaker downstream rival. Therefore, when facing a reliable rival, the integrated supplier prefers not to offer guarantees.

[20]This is the case whenever the compensation C exceeds δ: in particular, covering the innovator's loss in case of imitation (i.e., $C = \Delta - \delta$) would be suffficient. In practice, divulging confidential information may already make a supplier legally liable to some compensation; yet, the supplier can contractually offer enhanced protection, e.g., by increasing the amount to be paid and/or expanding the set of circumstances under which such compensation would be awarded.

The reliability decision of independent suppliers is instead driven solely by its impact on the upstream business. An unreliable supplier only obtains a positive margin when both downstream firms innovate (in which case reliability is a moot issue), whereas a reliable supplier also obtains a positive profit when only the downstream firm for which it constitutes a better supplier innovates (if the rival supplier is unreliable, it may even obtain a positive profit when the other downstream firm is the sole innovator). As a result, independent suppliers prefer to offer guarantees when reliability matters sufficiently more than product differentiation (that is, when γ is not too large).

3.3 Firewalls

Firewalls are information barriers implemented within a firm to ensure that confidential information is not passed on from one unit to another. In our framework, building effective firewalls enables suppliers, separated or not, to protect their customers' sensitive information. Setting up a firewall involves a cost (education of employees, divisions of tasks, control of employees,...), which firms may prefer to save at the expense of their reputation. To explore this issue, consider the same situation as before except that, in stage 0, each supplier must decide whether to publicly build a firewall at cost f.

We have:

Proposition 10 *As long as the benefit from differentiation is not too large, independent suppliers set-up firewalls whenever their costs is not excessive; in contrast, in case of partial integration the integrated supplier does not set up any firewall, in order to benefit from the resulting strategic foreclosure.*

Proof. See Appendix **??**. ■

This proposition derives from the previous one. Indeed, when f is close to zero, firms can again be reliable at (almost) no cost; obviously, when f is large, even independent suppliers may choose not to invest in firewalls.

3.4 Reputation

Whenever imitation creates a profitable foreclosure effect, a vertically integrated firm may have an incentive to exaggerate the threat of such imitation, for instance by downplaying the cost of imitation, so as to increase the market power of independent suppliers and thus raise downstream rivals' costs. In a dynamic setting, a vertically integrated firm may therefore engage in (even unobserved) costly imitation processes, in order to establish a reputation and benefit from strategic foreclosure in the following periods, in which the threat of imitation increases independent rivals' costs and thus strengthens the integrated firm's market power in the downstream market. We explore this more formally in the following section and show that building such a reputation may be profitable for an integrated firm, whereas independent suppliers would rather avoid this in order to keep attracting customers. We develop a dynamic reputation model in which firms differ according to their costs for reverse engineering: "bad" firms have a lower cost of imitation than "good" firms. In a context where, absent vertical integration, only bad firms imitate the innovation produced by their customers, vertical integration creates an incentive for good firms to do so as well, in order to appear being bad and benefit from the resulting foreclosure effect.

TO BE COMPLETED

4 References

- Anton, J. J. and D. Yao (1994), "Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights", *The American Economic Review*, 84 (1):190-209.

  Anton, J. J. and D. Yao (2002), "The Sale of Ideas: Strategic Disclosure, Property Rights and Contracting",*The Review of Economic Studies*, 69(3):513-531.

  Bhattacharya, S. and S. Guriev (2006), "Patent vs. Trade Secrets: Knowledge Licensing and Spillover", *Journal of the European Economic Association*, 4(6):1112-1147.

  Bonanno, G. and J. Vickers (1988) "Vertical Separation", *The Journal of Industrial Economics*, 36, (3): 257-265.

  Choi, J.-P. and S. Yi (2000),"Vertical Foreclosure with the Choice of Input Specifications" *RAND Journal of Economics*, 31(4):717-743.

  Gaudet, G. and N. Van Long (1996), "Vertical Integration, Foreclosure, and Profits in the Presence of Double Marginalization", *Journal of Economics and Management Strategy* 5(3):409-432.

  Hart, O. and J. Tirole (1990), "Vertical Integration and Market Foreclosure", *Brooking Papers on Economic Activity*, (Special issue), 205-76.

  Hughes, S.J. and L.J. Kao (2001), "Vertical integration and proprietary information transmission", *Journal of Economics and Management Strategy*, 10:277–299.

  Krattenmaker, T.G. and S.C. Salop (1986), "Anticompetitive Exclusion: Raising Rivals' Costs to achieve Power over Price", *The Yale Law Journal* 96: 209–293.

  Ma, A. (1997) "Option Contracts and Vertical Foreclosure" *Journal of Economics and Management Strategy* 6 (4): 725-753.

  McAfee, P. and M. Schwartz (1994), "Opportunism in Multilateral Vertical Contracting: Non Discrimination, Exclusivity and Uniformity", *The American Economic Review*, 84(1):210-230.

  Milliou, C. (2004), "Vertical Integration and R&D Information Flow: Is there a Need for Firewalls?", *International Journal of Industrial Organization* 22:25-43.

O'Brien, D. and G. Shaffer (1992), "Vertical Control with Bilateral Contracts", *RAND Journal of Economics*, 41(2): 215-221.

Ordover, J., S. Saloner and S. C. Salop (1990), "Equilibrium Vertical Foreclosure" *The American Economic Review*, 80 (1):127-142.

Ordover, J., S. Saloner and S. C. Salop (1992), "Equilibrium Vertical Foreclosure: Reply" *The American Economic Review*, 82:698-703.

Reiffen, D. (1992), "Equilibrium Vertical Foreclosure: Comment", *The American Economic Review*, 82:694-697.

Rey, P. and J. Tirole (2007), "A primer on Foreclosure", Handbook of Industrial organization III, edited by. Armstrong, M. and R. Porter.

Rey,P. and J. Stiglitz, (1995), "The Role of Exclusive Territories in Producers' Competition," *RAND Journal of Economics*,26(3),431-451.

Salinger, M. (1988), "Vertical Mergers and Market Foreclosure", *Quarterly Journal of Economics*, 103(2):345-356.

Shaffer, G. (1991), "Slotting allowances and retail price maintenance: a comparison of facilitating practices", *The RAND Journal of Economics*, 22, 1, pp.120-35.

Thomas, C.J. (1996), "Market Structure and the flow of information in repeated auctions", *Bureau of Economics*, Working Paper n°213.

A Appendix

A.1 Complementary investments

Suppose that the probability of successful imitation is equal to $\theta_U\theta_D$, where θ_U and θ_D are unobservable and respectively controlled by the upstream and downstream firms. Suppose further that: (i) each θ_i can take two values, high $\left(\overline{\theta}\right)$ or low $(\underline{\theta})$, with $0 < \underline{\theta} < \overline{\theta} \leq 1$; and (ii) opting for the low value $\underline{\theta}$ gives the controlling firm a private, non-transferable benefit $b > 0$, whereas successful imitation gives the downstream firm a monetary benefit $\delta > 0$.

- If the firms are vertically separated, in order to provide adequate incentives the downstream firm can pay some amount ϕ to the supplier in case of successful imitation. The risk of imitation is then maximal (that is, $\theta_U = \theta_D = \overline{\theta}$) if and only if:

- the upstream firm prefers $\overline{\theta}$ to $\underline{\theta}$, that is:

$$\overline{\theta\theta}\phi \geq \overline{\theta}\underline{\theta}\phi + b, \tag{21}$$

- the downstream firm does the same, that is:

$$\overline{\theta\theta}(\delta - \phi) \geq \overline{\theta}\underline{\theta}(\delta - \phi) + b. \tag{22}$$

  Summing-up these two conditions, the risk of imitation can be maximal only if:

$$\overline{\theta\theta}\delta \geq \overline{\theta}\underline{\theta}\delta + 2b, \tag{23}$$

  that is, only if: $\delta \geq \frac{2b}{(\overline{\theta}-\underline{\theta})\overline{\theta}}$.

- If instead the two firms are vertically integrated, the risk of imitation is maximal whenever the integrated firm prefers both divisions providing a high effort rather than:

  - only one doing so, which requires:

$$\overline{\theta\theta}\delta \geq \overline{\theta}\underline{\theta}\delta + b, \tag{24}$$

  - none doing so, which requires:

$$\overline{\theta}^2\delta \geq \underline{\theta}^2\delta + 2b. \tag{25}$$

  Of these two constraints, the latter is the most demanding[21] and can be rewritten as:

$$\delta \geq \frac{2b}{\left(\overline{\theta} - \underline{\theta}\right)\left(\overline{\theta} + \underline{\theta}\right)}, \tag{26}$$

  which is less demanding than the condition (**??**) required in the absence of vertical integration.

Therefore:

Proposition 11 *If* $\frac{2b}{\left(\overline{\theta}-\underline{\theta}\right)\left(\overline{\theta}+\underline{\theta}\right)} \leq \delta < \frac{2b}{\overline{\theta}(\overline{\theta}-\underline{\theta})}$, *only vertical integration allows the firms to achieve the maximal probability of successful imitation.*

[21]To see this, note that they are respectively equivalent to $b \leq \delta\left(\overline{\theta} - \underline{\theta}\right)\overline{\theta}$ and $b \leq \delta\left(\overline{\theta} - \underline{\theta}\right)\frac{\overline{\theta}+\underline{\theta}}{2}$. The conclusion then follows from $\overline{\theta} > \underline{\theta}$.

A.2 Reverse engineering

In this Appendix, we prove Proposition **??**, using the payoff matrix II introduced in section **??**, in which downstream firms each obtain δ when they both innovate (where $0 < \delta < \Delta/2$), and a general cost function $C(\rho)$ satisfying Assumption A.

As already established in Section **??**, no independent supplier will ever invest in reverse engineering. Therefore, when both suppliers are vertically separated, standard Bertrand competition among equally reliable suppliers yields $T_{Ai} = T_{Bi} = 0$ (even when only one downstream firm innovates). D_i's expected profit is therefore, for $i = 1, 2$ and $j \neq i$:

$$\hat{\Pi}(\rho_i, \rho_j) \equiv \rho_i (\rho_j \delta + (1 - \rho_j) \Delta) - C(\rho_i). \tag{27}$$

It follows that investment decisions are again strategic substitutes:

$$\frac{\partial^2 \hat{\Pi}}{\partial \rho_i \partial \rho_j} = -(\Delta - \delta) < 0, \tag{28}$$

and Assumption A still ensures that the symmetric best response, $\rho_i = \hat{R}(\rho_j)$ is interior $\left(0 < \hat{R}(\rho_j) < 1\right)$ and uniquely characterized by the first-order condition:

$$C'(\rho_i) = \rho_j \delta + (1 - \rho_j) \Delta. \tag{29}$$

Assumption A moreover implies that the best response satisfies: $\hat{R}(1) < 1$, $\hat{R}(0) > 0$, and

$$0 > \hat{R}'(\rho) = \frac{-(\Delta - \delta)}{C''\left(\hat{R}(\rho)\right)} > -1. \tag{30}$$

It follows that there exists a unique equilibrium, which is stable and symmetric: $\rho_1 = \rho_2 = \hat{\rho}^*$, characterized by the above first-order condition. Both downstream firms obtain an expected profit equal to $\hat{\Pi}^* \equiv \hat{\Pi}(\hat{\rho}^*, \hat{\rho}^*)$.

Compared to the equilibrium obtained for the payoff matrix I, investment levels are now higher ($\hat{\rho}^* > \rho^*$): the fact that downstream competition no longer fully dissipates innovation benefits ($\delta > 0$) moves best responses up (all the more so as δ increases) and, as a result, the (stable) equilibrium investment levels also increase. In both instances, however, upstream firms make no profit.

Suppose now that U_A and D_1, say, have merged, whereas U_B remains independent – and thus chooses to be reliable. As already noted in Section **??**, the integrated firm then never provides internal information to its independent rival; that is, vertical integration *de facto* protects D_1 against imitation. Moreover, if both firms innovate, a customer's information has no market value; whether a supplier is reliable is therefore irrelevant: standard Bertrand competition among the suppliers always yields $T_{Ai} = T_{Bi} = 0$ and thus each downstream firm obtains a profit equal to δ.

The only remaining relevant case is when D_2 is the sole successful innovator.

• If both $U_A - D_1$ and U_B are reliable, Bertrand competition drives again tariffs to zero. Expected downstream profits are thus again $\hat{\Pi}_i(\rho_i, \rho_j)$ and both investments are equal to $\hat{\rho}^*$. $U_A - D_1$'s expected profit is thus still equal to $\hat{\Pi}^*$.

• If instead $U_A - D_1$ is an unreliable supplier, it offers D_2 a subsidy of up to $T_{A2} = -\delta$ but U_B wins by charging $T_{B2} = \Delta - 2\delta$. The expected profits of the investing firms are then respectively:

$$\Pi_{A1} = \hat{\Pi}(\rho_1, \rho_2), \tag{31}$$

and

$$\Pi_2 = \underline{\hat{\Pi}}(\rho_2, \rho_1) \equiv \rho_2(\rho_1\delta + (1-\rho_1)2\delta) - C(\rho_2). \tag{32}$$

Therefore, the integrated downstream firm will behave as above ($\rho_1 = \hat{R}(\rho_2)$), but the independent firm will invest less than before, since it must share with U_B the value of its innovation when being the sole innovator. Its best response $\rho_2 = \underline{\hat{R}}(\rho_1)$ is characterized by the first-order condition:

$$C'(\rho_2) = \rho_1\delta + (1-\rho_1)2\delta \tag{33}$$

Since $2\delta < \Delta$, $\underline{\hat{R}}(\rho_1) < \hat{R}(\rho_1)$ and, since $\hat{R}'(\rho_2) < 0$, the equilibrium investments are thus of the form $\rho_2 = \hat{\rho}^- < \hat{\rho}^* < \rho_1 = \hat{\rho}^+$; $U_A - D_1$'s expected profit, $\hat{\Pi}^+ \equiv \hat{\Pi}(\hat{\rho}^+, \hat{\rho}^-)$, thus satisfies:

$$\hat{\Pi}^+ = \max_{\rho_1} \hat{\Pi}\left(\rho_1, \hat{\rho}^-\right) > \hat{\Pi}^* = \max_{\rho} \hat{\Pi}(\rho, \hat{\rho}^*).$$

$U_A - D_1$ will therefore invest in reverse engineering whenever $F < \hat{F} \equiv \hat{\Pi}^+ - \hat{\Pi}^*$.

A.3 Guarantees and firewalls

In this Appendix, we prove Propositions **??** and **??**, using again the payoff matrix II and a cost function satisfying Assumption A. To break indifference (as shown below, independent suppliers' profits would otherwise always be zero), we moreover assume that firm D_1 (resp. D_2) obtains a small surplus γ (in case of innovation) when buying from his favorite supplier U_A (resp. U_B).

Suppliers' reliability is irrelevant when both downstream firms' innovation efforts are successful. In that case, for each D_i, asymmetric Bertrand competition leads D_i's favorite supplier to win the competition with a tariff that extracts the surplus γ: for example, U_A offers D_2 a tariff $T_{A2} = 0$, but U_B wins with a tariff (slightly below) $T_{B2} = \gamma$. Likewise, U_A wins the competition for D_1 with a tariff $T_{A1} = \gamma$. As a result, each D_i obtains a profit equal to δ.

Suppliers' reliability instead matters when only one downstream firm successfully innovates. While an integrated supplier will always protect the information from its own subsidiary, unreliable suppliers would be willing to trade the information obtained from their independent customers. We now study the implications under vertical separation and partial integration.

Vertical separation.

• If both suppliers are reliable, then when only D_i innovates asymmetric Bertrand competition leads D_i's favorite supplier to win with a tariff reflecting its comparative advantage; D_i thus obtains Δ while its favorite supplier obtains γ. Each D_i's expected profit is therefore given by $\Pi_i = \hat{\Pi}(\rho_i, \rho_j)$, and equilibrium investments are thus $\rho_1 = \rho_2 = \hat{\rho}^*$. Suppliers' equilibrium expected profits are both equal to:

$$\hat{\Pi}_{VS}^{rr} \equiv \hat{\rho}^* \gamma.$$

• Suppose now that both suppliers are unreliable. If D_1, say, is the only successful innovator, asymmetric Bertrand competition yields $T_{B1} = -\delta$ and $T_{A1} = \gamma - \delta$; the favorite supplier then wins, and sells (at "full" price δ) the information to the downstream rival, who duplicates the innovation. Thus, D_1 obtains $\delta + \gamma - T_{A1} = 2\delta$ while its favorite supplier obtains $T_{A1} = \gamma - \delta$. Ex ante, each D_i's expected profits is thus $\Pi_i = \underline{\hat{\Pi}}(\rho_i, \rho_j)$. Both best responses are thus of the form $\rho_i = \underline{\hat{R}}(\rho_j)$ and equilibrium investments are symmetric: $\rho_1 = \rho_2 = \underline{\hat{\rho}}$, where $\underline{\hat{\rho}}$ satisfies $\underline{\hat{\rho}} < \hat{\rho}^*$. Suppliers' equilibrium expected profits are thus lower than before and now equal to

$$\hat{\Pi}_{VS}^{uu} \equiv \underline{\hat{\rho}} \gamma.$$

• Suppose now that U_A, say, is unreliable whereas U_B is reliable. As long as reliability matters more than suppliers' differentiation (namely, as long as $\gamma < \Delta - 2\delta$), then when D_i is the only successful innovator Bertrand competition results in U_A offering $T_{Ai} = -\delta$ and U_B winning with a tariff that leaves D_i almost indifferent between the two offers. Thus, when D_1 is the sole innovator, U_B charges $T_{B1} = \Delta - 2\delta - \gamma$ and D_1 obtains $2\delta + \gamma$; when instead D_2 is the only successful innovator, then U_B wins by offering $T_{B2} = \Delta - 2\delta + \gamma$ and D_2 obtains 2δ. The expected profits of the two downstream firms are thus respectively:

$$\Pi_1(\rho_1, \rho_2) = \tilde{\Pi}(\rho_1, \rho_2) \equiv \rho_1 (\rho_2 \delta + (1 - \rho_2)(2\delta + \gamma)) - C(\rho_1), \tag{34}$$

and

$$\Pi_2(\rho_1, \rho_2) = \underline{\hat{\Pi}}(\rho_2, \rho_1). \tag{35}$$

Best responses are therefore of the form $\rho_2 = \underline{\hat{R}}(\rho_1)$ and $\rho_1 = \tilde{R}(\rho_2)$, which is characterized by the first-order condition:

$$C'(\rho_1) = \rho_2 \delta + (1 - \rho_2)(2\delta + \gamma),$$

and thus satisfies $\underline{\hat{R}}(\rho) < \tilde{R}(\rho) < \hat{R}(\rho)$. Equilibrium investments are therefore asymmetric and such that $\rho_1 = \tilde{\rho}^+$ and $\rho_2 = \tilde{\rho}^-$, where $\tilde{\rho}^- < \underline{\hat{\rho}} < \tilde{\rho}^+$.

Note that U_A obtains a positive profit only when both downstream firms' innovation efforts are successful. Its expected profit is therefore equal to:

$$\Pi_A = \hat{\Pi}^{ur}_{VS} \equiv \tilde{\rho}^- \tilde{\rho}^+ \gamma, \tag{36}$$

whereas U_B's expected profit is equal to:

$$\Pi_B = \hat{\Pi}^{ru}_{VS} \equiv \tilde{\rho}^- \tilde{\rho}^+ \gamma + \tilde{\rho}^- \left(1 - \tilde{\rho}^+\right)(\Delta - 2\delta + \gamma) + \left(1 - \tilde{\rho}^-\right) \tilde{\rho}^+ (\Delta - 2\delta - \gamma).$$

U_A's expected profit is lower than $\hat{\Pi}^{rr}_{VS}$, since $\tilde{\rho}^- \tilde{\rho}^+ < \tilde{\rho}^- < \hat{\rho}^*$. As for U_B's expected profit, it exceeds $\hat{\Pi}^{uu}_{VS}$ whenever reliability matters sufficiently more than product differentiation. For example, when

$$\gamma < \hat{\gamma}^{VS} \equiv (\Delta - 2\delta)/2,$$

then ex post U_B obtains at least γ whenever at least one firm innovates, and thus

$$\hat{\Pi}^{ru}_{VS} > \tilde{\rho}^+ \gamma > \underline{\hat{\rho}} \gamma = \hat{\Pi}^{uu}_{VS}.$$

Therefore, as long as $\gamma < \hat{\gamma}^{VS}$ we have:

$$\hat{\Pi}^{uu}_{VS} < \hat{\Pi}^{ru}_{VS} \text{ and } \hat{\Pi}^{ur}_{VS} < \hat{\Pi}^{rr}_{VS}.$$

This, in turn, implies that offering a guarantee (which provides a costless way to become reliable) is a dominant strategy for each supplier in the guarantee game considered in section **??**. Similarly, in the firewall game considered in section **??**, setting up a firewall constitutes a dominant strategy whenever $f < \hat{f}^{VS} \equiv \min \left\{ \hat{\Pi}^{rr}_{VS} - \hat{\Pi}^{ur}_{VS}, \hat{\Pi}^{ru}_{VS} - \hat{\Pi}^{uu}_{VS} \right\}$.

Vertical integration.

Suppose now that U_A and D_1, say, are vertically integrated whereas U_B and D_2 remain independent. Vertical integration protects D_1 against imitation and moreover allows it to internalize the full value of its innovation.

• Suppose first that the independent supplier is at least equally reliable as the integrated supplier (that is, both suppliers are reliable, both are unreliable, or U_A is unreliable whereas U_B is reliable). $U_A - D_1$'s expected profit is then equal to:

$$\Pi_{A1} = \breve{\Pi}\left(\rho_1, \rho_2\right) \equiv \rho_1(1-\rho_2)(\Delta+\gamma) + \rho_1\rho_2(\delta+\gamma) - C\left(\rho_1\right), \tag{37}$$

The corresponding best response, $\rho_1 = \breve{R}\left(\rho_2\right)$, is characterized by the first-order condition:

$$C'\left(\rho_1\right) = \rho_2\delta + \left(1-\rho_2\right)\Delta + \gamma.$$

It thus satisfies $\breve{R}\left(\rho\right) > \hat{R}\left(\rho\right)$, $\breve{R}\left(0\right) > 0$, and:

$$0 > \breve{R}'\left(\rho\right) = \frac{-\left(\Delta-\delta\right)}{C''\left(\breve{R}\left(\rho\right)\right)} > -1. \tag{38}$$

D_2's expected profit is equal to $\hat{\Pi}\left(\rho_2, \rho_1\right)$ if both suppliers are reliable, and to $\underline{\hat{\Pi}}\left(\rho_2, \rho_1\right)$ if the integrated firm is not reliable;[22] therefore:

- When both suppliers are reliable, D_2's best response is given by $\rho_2 = \hat{R}\left(\rho_1\right)$; we will denote by $\left(\breve{\rho}_1, \breve{\rho}_2\right)$ the resulting equilibrium investments. Since U_B then extracts its comparative advantage γ whenever D_2 innovates, its expected profit is equal to:

$$\hat{\Pi}_B^{rr} \equiv \breve{\rho}_2\gamma.$$

- If instead U_A is not reliable, D_2's best response is given by $\rho_2 = \underline{\hat{R}}\left(\rho_1\right)$ and we will denote by $\left(\breve{\rho}^+, \breve{\rho}^-\right)$ the resulting equilibrium investments; simple comparative statics yield $\breve{\rho}^- < \breve{\rho}_2$ and $\breve{\rho}^+ > \breve{\rho}_1$. U_B extracts again its comparative advantage γ whenever D_2 innovates, but this benefit depends on its reliability decision:

  – If U_B is not reliable either, its expected profit is simply equal to:

$$\Pi_B = \hat{\Pi}_B^{uu} \equiv \breve{\rho}^-\gamma.$$

[22] D_2 obtains δ if both downstream innovation efforts are successful. If it is the sole innovator, it obtains Δ if both suppliers are reliable. If U_A is not reliable, then U_B will extract its comparative advantage (γ if it is unreliable, and $\gamma + \Delta - 2\delta$ if instead it is reliable) and leave only 2δ to D_2.

– If instead U_B is reliable, it benefits from a larger comparative advantage when only D_2 innovates and its expected profit is then:

$$\hat{\Pi}_B^{ru} \equiv \breve{\rho}^- \gamma + \left(1 - \breve{\rho}^+\right) \breve{\rho}^- \left(\Delta - 2\delta\right).$$

• Suppose now that the integrated supplier is more reliable than its independent rival. Then, when D_2 is the sole innovator U_B offers $T_{B2} = -\delta$ but $U_A - D_1$ wins by offering $T_{A2} = \Delta - 2\delta - \gamma$. The expected profits of the two investing firms are then equal to:

$$\Pi_{A1} = \mathring{\Pi}_1\left(\rho_1, \rho_2\right) \equiv \breve{\Pi}\left(\rho_1, \rho_2\right) + \rho_2(1 - \rho_1)\left(\Delta - 2\delta - \gamma\right), \tag{39}$$

and

$$\Pi_2 = \mathring{\Pi}_2\left(\rho_2, \rho_1\right) \equiv \rho_2(1 - \rho_1)(2\delta + \gamma) + \rho_1\rho_2\delta - C\left(\rho_2\right). \tag{40}$$

The corresponding best responses, $\rho_1 = \mathring{R}_1\left(\rho_2\right)$ and $\rho_2 = \mathring{R}_2\left(\rho_2\right)$, are respectively characterized by the first-order conditions:

$$C'\left(\rho_1\right) = \rho_2\left(\delta - \left(\Delta - 2\delta - \gamma\right)\right) + \left(1 - \rho_2\right)\Delta + \gamma,$$

$$C'\left(\rho_2\right) = (1 - \rho_1)(2\delta + \gamma) + \rho_1\delta.$$

We will denote by $(\mathring{\rho}_1, \mathring{\rho}_2)$ the corresponding equilibrium investments. U_B's expected profit in that case is equal to:

$$\Pi_B = \hat{\Pi}_B^{ur} \equiv \mathring{\rho}_1\mathring{\rho}_2\gamma.$$

Let us now study the reliability decisions. If $U_A - D_1$ chooses not to be reliable, U_B benefits from being reliable, since this increases its expected profit from $\hat{\Pi}_B^{uu}$ to $\hat{\Pi}_B^{ru} = \hat{\Pi}_B^{uu} + \left(1 - \breve{\rho}^+\right)\breve{\rho}^-\left(\Delta - 2\delta\right) > \hat{\Pi}_B^{uu}$. If instead $U_A - D_1$ chooses to be reliable, U_B's benefit from reliability is equal to:

$$\hat{\Pi}_B^{rr} - \hat{\Pi}_B^{ur} = \left(\breve{\rho}_2 - \mathring{\rho}_1\mathring{\rho}_2\right)\gamma.$$

When γ tends to zero, $\breve{\rho}_2$ converges to $\hat{\rho}^*$ whereas $(\mathring{\rho}_1, \mathring{\rho}_2)$ tends to $(\hat{\rho}^+, \hat{\rho}^-)$. In the limit, the difference $\breve{\rho}_2 - \mathring{\rho}_1\mathring{\rho}_2$ thus converges towards:

$$\hat{\rho}^* - \hat{\rho}^+\hat{\rho}^- > \hat{\rho}^* - \hat{\rho}^- > 0.$$

Therefore, there exists $\hat{\gamma}^{VI}$ such that $\hat{\Pi}_B^{rr} - \hat{\Pi}_B^{ur} > 0$ as long as $\gamma < \hat{\gamma}^{VI}$. In this range, in section **??** it is a dominant strategy for the independent supplier to offer a guarantee, and in section **??** it is also a dominant strategy to set-up a firewall as long as $f < \hat{f}^{VI} \equiv \min\left\{\hat{\Pi}_B^{rr} - \hat{\Pi}_B^{ur}, \hat{\Pi}_B^{ru} - \hat{\Pi}_B^{uu}\right\}$.

Consider now the reliability decision of the integrated firm, when facing a reliable rival. Choosing to be reliable yields an expected profit equal to $\breve{\Pi}(\breve{\rho}_1, \breve{\rho}_2)$, whereas choosing not to be reliable yields/

$$\breve{\Pi}\left(\breve{\rho}^+, \breve{\rho}^-\right) = \max_{\rho_1} \breve{\Pi}\left(\rho_1, \breve{\rho}^-\right) > \max_{\rho_1} \breve{\Pi}\left(\rho_1, \breve{\rho}_2\right) = \breve{\Pi}\left(\breve{\rho}_1, \breve{\rho}_2\right).$$

It follows that it is best for $U_A - D_1$ to be unreliable (by denying guarantees or by not setting-up firewalls), so as to benefit from the strategic foreclosure effect.

To recap:

- when $\gamma < \hat{\gamma} \equiv \min\left\{\hat{\gamma}^{VS}, \hat{\gamma}^{VI}\right\}$, it is always a dominant strategy for an independent supplier to offer guarantees in the game considered in section **??** – irrespective of whether its rival is independent or integrated, or reliable or not; it is also a dominant strategy for any independent supplier to set-up a firewall in the game considered in section **??** as long as the cost of doing so does not exceed $\hat{f} = \min\left\{\hat{f}^{VS}, \hat{f}^{VI}\right\}$.

- by contrast, when facing a reliable independent supplier, an integrated firm finds it optimal to appear unreliable (by not offering guarantees or not setting-up firewalls).