Vertical Integration, Innovation and Foreclosure[1]

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

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

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

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

Abstract

This paper studies the potential effects of vertical integration on downstream firms' incentives to innovate. To interact efficiently with suppliers, firms may have to provide sensitive information which, if disclosed to rivals, could facilitate imitation. We show that, by altering the supplier's incentives to protect or exploit its customers' information, vertical integration degrades the supplier's ability to interact with downstream competitors. This leads to input foreclosure, raises rivals' cost and limits both upstream competition and downstream innovation and development. A similar concern of customer foreclosure arises in the case of downstream bottlenecks.

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1 Introduction

This paper shows that, by fostering the risk of information leakage and imitation, vertical integration can reduce competitors' incentives to innovate. To interact efficiently, firms may have to provide sensitive information to their suppliers, which creates a risk of information dissemination.[1] This concern is particularly serious for innovative industries, where information disclosure can foster imitation. As we will see, an integrated supplier can be more tempted to pass on such information to its subsidiary. Vertical integration then results in input foreclosure, not because the integrated firm refuses to supply unaffiliated rivals, but simply because it becomes less reliable. This strengthens the market power of alternative suppliers, "raises rivals' costs", and impedes innovation.[2] A similar concern of customer foreclosure arises in the case of downstream bottlenecks.[3]

This issue is a growing concern for the European Commission, who mentions for example in its *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."[4] This issue has also been raised in a number of merger cases.[5]

A recent European example is the merger between TomTom and Tele Atlas.[6] TomTom manufactures portable navigation devices (or "PNDs"), whereas Tele Atlas was one

[1] Asker and Ljungqvist (2010) show for instance that due to the fear of information leakages, firms refrain from using the same investment bank as their direct competitors.

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

[3] 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.

[4] *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.

[5] 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 for example discussed in such merger cases as 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).

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

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."[7] Third parties feared that "[a]ccess to information about the future behavior of its downstream customers, would allow the merged firm to preempt 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 cooperate 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".[8]

In the US, the FTC put conditions in 2010 on a vertical merger between PepsiCo and its two largest bottlers and distributors in North America who were also acting as bottlers and distributors for its rival Dr Pepper Snapple (henceforth "DPSG"). Yet the FTC expressed his concern that "PepsiCo will have access to DPSG's commercially sensitive confidential marketing and brand plans. Without adequate safeguards, PepsiCo could misuse that information, leading to anticompetitive conduct that would make DPSG a less effective competitor [...]".[9] The FTC ordered PepsiCo to set up a firewall

[7] Commission decision at § 256.

[8] Commission decision at § 253. Interestingly, at about the same time, Nokia (another manufacturer of PNDs) acquired NAVTEQ, which raised similar concerns (see COMP/M.4942 - NOKIA/NAVTEQ, 02/07/2008).

[9] See FTC 2010; The FTC was also concerned by the risk of facilitated coordination in the industry.

in order to regulate the use of this commercially sensitive information.[10]

Our analysis supports these concerns. We consider a bilateral duopoly framework in which, to develop innovation, firms must share with their suppliers some information, which cannot be protected by traditional intellectual property rights. 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's innovation efforts and expands the merging parties' profit at the expense of independent rivals. We check that this insight is robust to variations 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 then discuss several reasons why an integrated firm may indeed be more likely to exploit its (independent) customers' information. Vertical integration may for example make it easier to transmit such information discreetly to its own subsidiary (or more difficult to prevent leakages). It may also enhance coordination between the upstream and downstream efforts required for successful imitation. But, more to the point, vertical integration fosters the merged entity's incentives to protect customers' information; that is, strategic motives exacerbate the risk of imitation. An integrated firm may for example choose to invest in reverse engineering technology where an independent supplier would not do so. 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 model before showing, in a dynamic setting, how vertical integration affects the merged entity's incentives to build a reputation of reliability.

Our paper 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 can be profitable as it allows the integrated firm to raise rivals' costs, by degrading their access to its own supplier and increasing in

[10] See FTC's decision and order "In the Matter of PepsiCo Inc", case 0910133 of 02/26/2010. The FTC put similar conditions on Coca Cola's acquisition of its largest North American bottler (See FTC's decision and order "In the Matter of The Coca-Cola Company", case 1010107 of 09/27/2010).

this way the market power of alternative suppliers.[11] Salinger (1988) obtains the same result in a successive Cournot oligopoly framework where integrated firms are supposed to exit the intermediate market.

As pointed out by Reiffen (1992), 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. By contrast, in our model, increasing alternative suppliers' market power adversely affects unintegrated rivals' R&D incentives even if supply contracts are ex-post efficient.

Hart and Tirole (1990) and Reiffen (1992) moreover stress that OSS and Salinger's analyses rely on the assumption that the integrated firm can somehow commit itself to limiting its supplies to downstream rivals – otherwise, it would have an incentive to keep competing with the alternative suppliers.[12] Several papers have explored ways to dispense with this commitment assumption. For example, Gaudet and Long (1996) show 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. Ma (1997) shows that foreclosure obtains without any commitment when the suppliers offer complementary components of downstream bundles.[13] In case of vertical separation, the competitive downstream industry makes no profit and offers at prices reflecting input costs. By contrast, when one of the suppliers integrates downstream, it has an incentive to stop supplying its component to downstream rivals, so as to monopolize the market for the bundle. Choi and Yi (2000) revisit the commitment issue by showing that an integrated supplier can find profitable to offer an input specifically tailored to the needs of its downstream unit, rather than a generic input. In a close spirit, Church and Gandal (2000) show that an integrated firm, producing both software and hardware, can find it profitable to make its software incompatible with a rival's hardware

[11] 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 a literature overview.

[12] Note that if the integrated firm can indeed commit to stop supplying downstream rivals, efficient contracting (e.g., two-part tariffs) among independent firms need not result into cost-based marginal input prices, as rivals may "dampen competition" by maintaining above-cost transfer prices – see Bonanno and Vickers (1988), Rey and Stiglitz (1995) and Shaffer (1991).

[13] In Ma's paper, the inputs are differentiated substitutes, but complementarity arises from uncertainty about consumers' relative preferences, which leads the downstream firms to offer "bundles" in the form of option contracts.

in order to depreciate that product. Finally, imperfect competition in the upstream market (combined with linear input prices) can yield partial foreclosure even in the absence of commitment. By contrast, we do not assume here that the integrated supplier can commit itself to not dealing with rivals. By exacerbating the risk of information leakages, a vertical merger *de facto* degrades the perceived quality of the integrated supplier, so that while the integrated firm wishes to keep supplying its rivals, the rivals become less keen to do so.[14]

Our paper is also related to the literature on innovation and product imitation. Anton and Yao (2002) highlight the tradeoff that inventors face in order to develop their innovation when, as in our setup, sensitive information cannot be protected by intellectual property rights: they must provide enough information to attract developers, who may then appropriate the innovation without compensation. A similar tension arises in our framework, and we consider its implications for R&D competition and vertical integration. Bhattacharya and Guriev (2006) investigate the impact of the risk of information leakages and imitation on the choice of licensing arrangements. In a framework where an inventor bargains with two competing developers, they compare patenting (which involves some upfront public disclosure but allows for exclusive licensing) to private negotiations (which limit public disclosure but allow the inventor to behave opportunistically and sell the information to both rivals). Although patenting is socially preferable, the inventor may opt for a private negotiation when for example disclosure is substantial, as this reduces the value of a patent and moreover reduces the risk of opportunism.

Several papers study more specifically the role of firewalls protecting the proprietary information received from third parties. For instance, Hughes and Kao (2001) consider a market structure where an integrated firm competes with less efficient rivals to supply downstream competitors, among which one has private information about demand. By supplying that firm, the integrated supplier obtains the information and shares it with its downstream subsidiary, which strengthens competition. In equilibrium, the integrated firm keeps supplying the rival, but must offer a more attractive price to compensate for information disclosure. A firewall would instead enable the integrated firm to raise its

[14] Chen (2001) and Chen and Riordan (2007) stress instead that independent firms may favor the integrated supplier, in order to relax downstream competition: the integrated firm then becomes less aggressive on the downstream market, to preserve its upstream profit.

price, and lower welfare.

Our paper is also close to Milliou (2004), who studies the impact of firewalls on downstream firms' R&D incentives; she considers the case of an upstream bottleneck and shows that a firewall enhances rivals' incentives to innovate but reduces the incentives of the integrated firm (in case of complementary R&D paths) or enhances them (in case of substitutes). In both cases, the integrated firm innovates more in the absence of a firewall, however, as it then benefits from the information flow. By contrast, we consider a 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 a firewall would therefore affect neither its abillity nor its incentives to innovate. A firewall would however restore rivals' R&D incentives and hence welfare.

The article is organized as follows. Section 2 develops a simple R&D model in which the risk of information leakages and imitation is exogenous; we first show how vertical integration results in foreclosure, before providing robustness checks and discussing welfare implications. The following sections discuss several reasons why vertical integration can indeed increase the threat of imitation, first in a static framework where firms can publicly commit to be reliable or not (section 3), and then in a dynamic framework without any such commitment (section 4). Section 5 concludes.

2 Foreclosure through the risk of imitation

To present the main intuition in a simple way, we postulate here as a working assumption that, contrary to independent suppliers, an integrated supplier always exploits its customers information. In the next sections, we show that this assumption indeed holds when both integrated and independent suppliers can 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.[15]

Downstream firms may innovate to increase the value of their offering. When one firm innovates, its comparative advantage generates an additional profit $\Delta > 0$. However, when both firms innovate, competition dissipates part of this profit and each firm then obtains $\delta < \Delta/2$.[16] Normalizing to zero the profits achieved in the absence of innovation, the payoff matrix is thus as follows, where I and N respectively denote "Innovation" and "No innovation":

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

(1)

Each D_i decides how much to invest in $R\&D$, and can innovate with probability ρ_i by investing $C(\rho_i)$. We will adopt the following regularity conditions:

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

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

$A(i)$ ensures that best responses are well behaved; $A(ii)$ and $A(iii)$ moreover imply that innovation probabilities 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

[15] 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 offer an efficient contract, in which the marginal transfer price reflects the marginal cost (normalized here to 0).

[16] Suppose for instance that the innovation creates a new product. If only one firm innovates, it obtains a monopoly profit, π^M; if instead both firms innovate, they share a lower duopoly profit $\pi^D < \pi^M$. We then have $\Delta = \pi^M$ and $\delta = \pi^D/2 < \Delta/2$.

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 θ the integrated firm successfully mimics the innovation (at no cost).

2.2 Vertical separation

Since the two suppliers produce the same input with the same constant unit cost, in the second stage upstream competition yields $T_{Ai} = T_{Bi} = 0$. In the first stage, each D_i chooses its *R&D* effort ρ_i so as to maximize its expected profit, given by:

$$\pi_i = \Pi\left(\rho_i, \rho_j\right) \equiv \rho_i \left(\rho_j \delta + \left(1 - \rho_j\right) \Delta\right) - C\left(\rho_i\right). \tag{2}$$

It follows that *R&D* efforts are strategic substitutes:

$$\frac{\partial^2 \Pi_i}{\partial \rho_i \partial \rho_j} = -\left(\Delta - \delta\right) < 0. \tag{3}$$

Let $\rho_i = R\left(\rho_j\right)$ denote D_i's best response to $\rho_j \in [0, 1]$ (by construction, these best responses are symmetric); Assumption A ensures that it is uniquely characterized by the first-order condition:

$$C'\left(\rho_i\right) = \rho_j \delta + \left(1 - \rho_j\right) \Delta, \tag{4}$$

and that it yields a unique equilibrium,[17] which is symmetric, interior and stable:[18]

Lemma 1 *In case of vertical separation, under Assumption A the best response $R(\rho)$ is differentiable and satisfies:*

$$0 \leq R(\rho) < 1, \tag{5}$$

[17] We assume that fixed costs, if any, are small enough (*e.g.*, $C(0) = 0$) to ensure that expected profits are always positive and thus that entry or exit is not an issue.

[18] That is, the slope of the best responses is lower than 1 in absolute value.

where the first inequality is strict whenever $\rho < 1$*, and:*

$$-1 < R'(\rho) < 0. \tag{6}$$

As a result there exists a unique equilibrium, which is symmetric and such that (where the superscript VS *refers to Vertical Separation):*

$$0 < \rho_1^{VS} = \rho_2^{VS} = \rho^* < 1. \tag{7}$$

Proof. The convexity assumption, together with the boundary conditions $A(ii)$ and $A(iii)$, ensures that the best response to $\rho_j \in [0,1]$, $\rho_i = R(\rho_j)$, is uniquely characterized by the first-order condition (4) and satisfies (5), with $R(\rho) > 0$ whenever $\rho < 1$. Differentiating (4) moreover yields:

$$R'(\rho) = \frac{-(\Delta - \delta)}{C''(R(\rho))} < 0.$$

We thus have: (i) $R'(\rho) < 0$, (ii) $R(0) > 0$, and (iii) $R(1) < 1$. Therefore, there is a unique ρ^* such that $\rho^* = R(\rho^*)$, and $0 < \rho < 1$. By construction, $\rho_1 = \rho_2 = \rho^*$ constitutes a symmetric equilibrium. Conversely, $A(i)$ implies $R'(\rho) > -1$, ensuring that the equilibrium is unique and stable. ■

2.3 Vertical integration

Suppose now that U_A and D_1 merge, and let $U_A - D_1$ denote the integrated firm. In the second stage of the game, the two suppliers remain equally effective as long as D_2 is not the only innovator; upstream competition then leads the suppliers to offer cost-based tariffs. When instead D_2 is the sole innovator, dealing with the integrated supplier exposes D_2 to imitation with probability θ and thus reduces D_2's expected gross profit to $\theta\delta + (1-\theta)\Delta < \Delta$; U_A is however willing to offer a discount equal to the expected value from imitation, $\theta\delta$. Asymmetric competition then leads U_A to offer $T_{A2} = -\theta\delta$

and U_B to win[19] with $T_{B2} = \theta(\Delta - 2\delta)$, giving D_2 a net profit:

$$\theta\delta + (1-\theta)\Delta - T_{A2} = \Delta - T_{B2} = \Delta - \theta(\Delta - 2\delta).$$

In the first stage, the integrated firm $U_A - D_1$'s expected profit is as before equal to $\pi_{A1} = \pi_1 = \Pi(\rho_1, \rho_2)$, given by (2), whereas D_2's expected profit becomes:

$$\pi_2 = \Pi_\theta(\rho_2, \rho_1) \equiv \rho_2(\rho_1\delta + (1-\rho_1)(\Delta - \theta(\Delta - 2\delta))) - C(\rho_2). \quad (8)$$

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

$$C'(\rho_2) = \rho_1\delta + (1-\rho_1)(\Delta - \theta(\Delta - 2\delta)). \quad (9)$$

$R_\theta(.)$ coincides with $R(.)$ for $\theta = 0$ and is identically equal to zero when $\theta = 1$ and $\delta = 0$. Furthermore, for $\rho < 1$, $R_\theta(\rho)$ strictly decreases as θ increases. As a result:

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

$$\rho_1^{VI} = \rho_\theta^+, \rho_2^{VI} = \rho_\theta^-, \quad (10)$$

where $\rho_0^+ = \rho_0^- = \rho^*$, and ρ_θ^+ and ρ_θ^- respectively increase and decrease as θ increases from 0 to 1.

Proof. When $\theta = 1$ and $\delta = 0$, $R_\theta(.) = 0$; the integrated firm then behaves as a monopolist and invests $\rho_1 = \rho^m \equiv R(0)$. Suppose now that $\theta < 1$ and/or $\delta > 0$. The convexity assumption, together with the boundary conditions $A(ii)$ and $A(iii)$, ensures that D_2's best response to $\rho_1 \in [0,1]$, is uniquely characterized by the first-order condition (9) and satisfies $0 \leq R_\theta(\rho) < 1$, with $R_\theta(\rho) > 0$ whenever $\rho < 1$.

[19] Contrary to Chen (2001) and Chen and Riordan (2007), upstream tariffs do not influence here the intensity of downstream competition; the risk of opportunistic behavior then ensures that in equilibrium D_2 always favors U_B.

Differentiating (9) yields:

$$R'_\theta(\rho) = -\frac{\Delta - \delta - \theta(\Delta - 2\delta)}{C''(R_\theta(\rho))} < 0. \tag{11}$$

$R_\theta(.)$ thus also satisfies $R_\theta(1) < 1$, $R_\theta(0) > 0$, $R'_\theta(0) < 0$, and (using condition $A(i)$) $R'_\theta(\rho) > -1$, implying again the existence of a unique, stable equilibrium, in which the R&D efforts satisfy $\rho_\theta^+ = R\left(\rho_\theta^-\right)$ and $\rho_\theta^- = R_\theta\left(\rho_\theta^+\right)$. Clearly, $\rho_0^+ = \rho_0^- = \rho^*$ since $R_0(.)$ coincides with $R(.)$. Finally, differentiating (4) and (9) with respect to ρ_θ^+, ρ_θ^- and θ yields:

$$\frac{d\rho_\theta^+}{d\theta} = \frac{\left(1-\rho_\theta^+\right)(\Delta-\delta)(\Delta-2\delta)}{C''\left(\rho_\theta^+\right)C''\left(\rho_\theta^-\right) - (\Delta-\delta)(\Delta-\delta-\theta(\Delta-2\delta))} > 0, \tag{12}$$

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

$$\frac{d\rho_\theta^-}{d\theta} = \frac{-\left(1-\rho_\theta^+\right)C''\left(\rho_\theta^+\right)(\Delta-2\delta)}{C''\left(\rho_\theta^+\right)C''\left(\rho_\theta^-\right) - (\Delta-\delta)(\Delta-\delta-\theta(\Delta-2\delta))} < 0. \tag{13}$$

■

In what follows, we denote by $\pi_{A1}^{VI} \equiv \pi_{A1}(\rho_1^{VI}, \rho_2^{VI})$ the equilibrium profit of the integrated firm, by $\pi_2^{VI} \equiv \pi_2(\rho_2^{VI}, \rho_1^{VI})$ the profit of the independent downstream firm and by $\pi_B^{VI} \equiv T_{B2} = \theta(\Delta - 2\delta)$ the profit of the rival supplier.

2.4 Input foreclosure

Vertical integration has no impact in the absence of imitation concerns: if $\theta = 0$, both providers, integrated or not, offer to supply at cost. By contrast, introducing a risk of imitation ($\theta > 0$) *de facto* reduces the "quality" of the integrated supplier for the independent competitor; this enhances the other supplier's market power and thus raises the cost of supply for the downstream rival, who must share with the supplier the benefit of its R&D effort. This "input foreclosure" 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, increases with the risk of imitation θ. As long as this risk remains limited ($\theta < 1$ and/or $\delta > 0$), 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"). By contrast, when the imitation concern is maximal ($\theta = 1$ and $\delta = 0$), the integrated supplier provides no value for the independent firm; the independent supplier can 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 – all the more so as the probability of imitation, θ, increases; in particular, when vertical integration exposes for sure to imitation ($\theta = 1$) and competition fully dissipates profits ($\delta = 0$), 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 ρ_θ^- and ρ_θ^+ respectively decrease and increase as θ increases, and that they both coincide with ρ^* for $\theta = 0$, whereas $\rho_\theta^- = 0$ for $\theta = 1$ and $\delta = 0$. As for part (ii), it suffices to note that $\rho_\theta^- < \rho^* < \rho_\theta^+$ implies:

$$\pi_{A1}^{VI} = \pi_\theta^+ \equiv \max_{\rho_1} \Pi\left(\rho_1, \rho_\theta^-\right) > \pi^* \equiv \max_{\rho_1} \Pi\left(\rho_1, \rho^*\right) = \pi_1^{VS} = \pi_A^{VS} + \pi_1^{VS},$$

and:

$$\pi_B^{VI} + \pi_2^{VI} = \Pi\left(\rho_\theta^-, \rho_\theta^+\right) < \max_{\rho_2} \Pi\left(\rho_2, \rho_\theta^+\right) < \max_{\rho_2} \Pi\left(\rho_2, \rho^*\right) = \pi_2^{VS} = \pi_B^{VS} + \pi_2^{VS},$$

where the first inequality stems from the fact that ρ_θ^- is chosen by D_2 so as to maximize its own profit, $\Pi_\theta\left(\rho_2, \rho_\theta^+\right)$, rather than the joint profit $\Pi\left(\rho_2, \rho_\theta^+\right)$ of the independent firms. Since $\pi_B^{VI} \geq \pi_B^{VS} = 0$, the last inequality also implies $\pi_2^{VI} < \pi_2^{VS}$. ■

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, who reduces its innovation effort. This input foreclosure thus benefits the integrated firm, $U_A - D_1$, who faces a less aggressive rival. Due to strategic substitution, the integrated firm moreover responds by increasing its investment, which not only further degrades D_2's profit but also degrades the joint profits of the independent firms.[20]

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 $\theta(\Delta - 2\delta)$ then simply becomes $\left(\overline{\theta} - \underline{\theta}\right)(\Delta - 2\delta)$.

Bilateral bargaining power. The same logic applies when downstream firms have significant bargaining power in their bilateral procurement negotiations, as long as suppliers obtain a share $\lambda > 0$ of the specific gains generated by the relationship. This does not affect the outcome in case of vertical separation: since the suppliers are then equally effective, there is no specific gain to be shared and downstream firms still obtain the full benefit of their innovation; R&D efforts are therefore again given by $\rho_1^{VS} = \rho_2^{VS} = \rho^*$. By contrast, in case of vertical integration the independent supplier obtains a share λ of its comparative advantage whenever D_2 is the only innovator (that is, $T_{B2} = \lambda\theta(\Delta - 2\delta)$); D_2's expected profit becomes:

$$\pi_2 = \Pi_{\lambda\theta}(\rho_2, \rho_1) \equiv \rho_2 (\rho_1 \delta + (1 - \rho_1)(\Delta - \lambda\theta(\Delta - 2\delta))) - C(\rho_2). \tag{14}$$

The same analysis then applies, replacing θ with the "adjusted probability" $\lambda\theta$, which

[20] The joint profit of U_B and D_2 is furthermore impaired by coordination failure in D_2's investment decision (that is, $\rho^- < R(\rho^+)$). Also, while here U_B can only benefit from foreclosure (since it obtains no profit in 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 can increase, since the integrated firm raises its price in the downstream market.

now depends on the relative bargaining power of the supplier as well as on the risk of imitation.

Imperfect imitation. In practice, imitators may exert less competitive pressure than a genuine innovator: an 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 some L, 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. Factors such as product differentiation, capacity constraints, quantity rather than price competition, and so forth, may limit the competition that arises when both firms innovate, and increase the resulting profit δ. Yet, partial foreclosure still arises as long as imitation reduces total industry profit ($\Delta > 2\delta$).

Imperfect competition in the upstream market. The above reasoning carries over to the case where suppliers produce imperfect substitutes. Suppose for example that each downstream firm has a favored supplier: D_1 (resp. D_2) obtains an additional surplus γ when dealing with U_A (resp. U_B), say. If D_2 is the sole innovator, then an integrated U_A still offers D_2 a subsidy $T_{A2} = -\theta\delta$, but U_B now wins the competition for D_2 with an even higher tariff, $T_{B2} = \theta(\Delta + \gamma - 2\delta)$. Conversely, if U_A were D_2's favored supplier, U_B would still be able to extract a rent from D_2's innovation as long as the comparative advantage does not offset reliability concerns (i.e., as long as $\gamma < \Delta - 2\delta$). The foreclosure effect is however stronger when a downstream firm merges with its own favored supplier.[21]

Number of competitors. The analysis clearly does not rely on the restriction to duopolies. Vertical integration would similarly enhance the market power of the independent supplier over any additional stand-alone downstream firm, thus discouraging its 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, so that degrading the perceived quality of the integrated supplier enhances the market power of the others over the independent downstream firms.

Suppliers versus developers. The analysis remains formally the same when upstream

[21] A formal derivation is presented at the end of Appendix E.

firms are "pure developers", needed only when an R&D project succeeds. A downstream firm (innovator) still obtains no profit in case of failure; and in case of success, an independent innovator will again have to share the value of its innovation with an independent developer whenever dealing with an integrated one creates a risk of imitation. We will use either interpretation.

Timing of negotiations. We have assumed so far that negotiations take place only after the outcome of $R\&D$ (ex post contracting), which makes sense when for example 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: in case of integration, the independent supplier then imposes a tariff reflecting its expected comparative advantage, $T_{B2} = \theta(1-\rho_1)\rho_2(\Delta - 2\delta)$, and this has exactly the same impact on D_2's incentives to invest. Both timings expose downstream firms to a potential "hold-up", which upstream competition however limits; vertical integration then results in foreclosure by weakening the pressure on the independent supplier, which allows it to behave more opportunistically.

Such hold-up problems coul be avoided if suppliers could commit themselves before downstream firms take their investment decisions, in which case foreclosure would no longer arise. If for example firms could agree on lump-sum payments, not contingent on the success of innovation efforts, vertical integration might still increase the market power of independent suppliers, and thus their tariffs, but would no longer reduce $R\&D$ investments. Such arrangements however raise several concerns. Liquidity constraints may for example call for deferred payments, which in turn triggers credibility issues, particularly when downstream firms have limited access to credit. To see this, suppose that downstream firms are initially cash constrained, and have moreover no access to credit; they must therefore pay their suppliers out of realized profits. The best contracts then boil down to milestone payments, conditional upon the success or failure of the innovation efforts. Consider for example the case where $\delta = 0$ and $\theta = 1$, in which case ex post contracting yields complete foreclosure: since U_B would fully appropriate the benefit from innovation, D_2 does not invest – and U_B thus obtains zero profit. With ex ante contracting, U_B can instead commit itself to not appropriating the full value of innovation. Yet, since D_2's payment can only come out of its innovation profit (when being the sole innovator), U_B's market power still reduces investment incentives.

Letting T denote D_2's payment, D_2's expected profit becomes $\rho_2(1-\rho_1)(\Delta - T)$ and the resulting investment levels are of the form $(\rho_1(T), \rho_2(T))$, where $\rho_1(.)$ and $\rho_2(.)$ respectively increase and decrease with T, and $\rho_2(\Delta) = 0$. Ex ante, U_B sets T so as to maximize its expected profit, $\pi_B(T) = \rho_2(T)(1-\rho_1(T))T$. The optimal tariff then satisfies $T^* < \Delta$, as it takes into consideration the negative impact of T on D_2's investment, and U_B and D_2 thus both obtain a positive profit. Yet, the hold-up problem remains, even if to a more limited extent, and foreclosure still arises.

Customer foreclosure. The analysis also applies ("upside-down") when manufacturers must exchange information with their distributors in order to launch new products. Concerns about information leaks then militate for relying on a single distributor where feasible. Vertical integration, as in the case of the acquisition of downstream bottlers and wholesalers by PepsiCo or CocaCola, or the development of private labels by large retail chains, may there again exacerbate the risk of information leaks and discourage manufacturer's innovation.[22]

Consider for instance the following framework, that mirrors the previous one. Suppose that: (i) two manufacturers U_A and U_B develop a new product with probabilities ρ_A and ρ_B by investing $C(\rho_A)$ and $C(\rho_B)$; (ii) whenever a new product is developed, two wholesalers (e.g., importers, or bottlers in the case of sodas or beers) then simultaneously compete for its exclusive distribution; 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.

Under similar cost and profit conditions as before, the equilibrium outcome is again symmetric ($\rho_A = \rho_B = \rho^*$) in case of vertical separation, and asymmetric, of the form $\rho_A = \rho_\theta^+ > \rho_B = \rho_\theta^-$, when 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.

Productivity investments, expansion projects and business strategies. Finally, while we have focused on risky innovation projects, our analysis applies as well to less uncertain productivity gains, development plans, capacity investments, and so forth, that enhance firms' competitiveness but require prior communication and information exchanges with

[22] In a recent market study, DIW reports that new national brand products are imitated more quickly by private labels (with an average delay of 10, 9 month) than by other national brands (12, 3 months). Similar observations apply for packaging imitation (Zunehmende Nachfragemacht des Einzelhandels, Eine Studie fur den Markenverband (DIW Econ)).

upstream or downstream partners. Suppose for example that:

- Downstream competition depends on firms' "effective capacities", κ_1 and κ_2: each D_i obtains Cournot-like revenues of the form $\pi(\kappa_i, \kappa_j) \equiv P(\kappa_1 + \kappa_2)\kappa_i$, where the "inverse demand function" satisfies $P'(.) < 0$ and $P'(\kappa) + P''(\kappa)\kappa < 0$, implying that capacities are strategic substitutes.

- Each κ_i depends on D_i's investment decision, ρ_i, and requires cooperation from the supplier, which an integrated firm can use to enhance its own effective capacity; as a result, $\kappa_i = \rho_i$ when an independent firm is involved, but $\kappa_1 = \rho_1 + \theta\rho_2$ when D_2 deals with an integrated U_A.

- The timing is as follows: first, downstream firms choose their investments, ρ_1 and ρ_2, and incur the associated costs; second, U_A and U_B compete for the development of each downstream firm's effective capacity; third, downstream competition yields the above-described profits.

When both suppliers are independent, upstream competition leads them to supply at cost; the above regularity conditions imply that capacity decisions are strategic substitutes and that there is a unique, stable symmetric equilibrium of the form $\rho_1 = \rho_2 = \rho^*$. When instead U_A and D_1 are vertically integrated, then the integrated firm would benefit from the independent downstream firm's capacity. The integrated firm is thus willing to offer U_2 a subsidy but we show in appendix A that, as long as total capacity $\rho_1 + \rho_2$ exceeds the joint revenue-maximizing level, U_B wins the competition at a positive price and foreclosure therefore arises.

2.6 Rivals' counter-fighting strategies

To counter the input foreclosure effect of a first vertical merger, the rivals can "fight back" by integrating as well. This eliminates the risk of imitation and thus yields the same outcome as in the absence of any merger: the two downstream firms are supplied at cost by their integrated suppliers, invest $\rho_1 = \rho_2 = \rho^*$ and thus obtain Π^*; the rivals thus indeed have an incentive to merge in response to a first vertical merger.

This however requires the availability of an alternative supplier for each and every downstream firm; otherwise, post-merger the integrated firms would still benefit from foreclosing the remaining independent downstream competitors. Consider for example the same setting as before, except that there are now $n > 2$ downstream firms. In case of vertical separation, both suppliers would then be reliable and sell at cost to all downstream firms. To be sure, a merger between U_A and D_1, say, may encourage D_2, say, to merge with U_B. But as the two suppliers would become less reliable for the remaining independent firms, downstream competition would again be biased in favor of the integrated firms. Such integration wave would thus confer a strategic advantage to the merging parties to the detriment of the independent rivals, who would again decrease their R&D efforts.[23]

Even in our duopoly model, a first merger can be profitable when integration is costly, since an initial merger may no longer lead the rivals to integrate; letting K denote the cost of integration, this is the case when:

$$\underline{K} \equiv \pi^* - \left(\pi_B^{VI} + \pi_2^{VI}\right) < K < \overline{K} \equiv \pi_{A1}^{VI} - \pi^*. \tag{15}$$

The interval $\left[\underline{K}, \overline{K}\right]$ is empty when $\Pi^{VI} \equiv \pi_{A1}^{VI} + \pi_B^{VI} + \pi_2^{VI} < \Pi^{VS} \equiv 2\pi^*$, *i.e.*, when a merger decreases total industry profit. In that case, a vertical merger either is unprofitable or triggers a counter-merger that eliminates any strategic advantage for the first merging firms. Otherwise, we have:

Proposition 4 *When partial integration raises total industry profit, there exists a non-empty range* $\left[\underline{K}, \overline{K}\right]$ *such that, whenever the integration cost* K *lies in this range, 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 benchmark case, in which duplication dissipates profit and R&D costs follow a standard quadratic specification:

Assumption B:

$$\delta = 0, C(\rho) = \frac{k}{2}\rho^2.$$

[23] This discussion applies for example to the TomTom/TeleAtlas and Nokia/Navteq mergers discussed in the introduction.

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. See appendix B. ■

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).[24] 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 ($\eta \geq 2$), 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 generates overinvestment, 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, focus on the polar case of complete foreclosure $\theta = 1$. Vertical integration then de facto implements the integrated industry optimum, and thus raises industry profit, whenever $\eta < 2$. 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.

2.7 Welfare analysis

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

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

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

before considering its impact on consumer surplus and total welfare.

Proposition 6 *Partial vertical integration reduces total investment; it also reduces the probability of innovation ϱ 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 $\varrho_\theta \equiv \rho_\theta^+ + \rho_\theta^- - \rho_\theta^+ \rho_\theta^-$ in the case of partial integration and $\varrho^* \equiv \varrho_0$ in the case of separation. Under Assumption A, total investment decreases when θ increases:

$$\frac{d(\rho_\theta^- + \rho_\theta^+)}{d\theta} = \frac{\left(1 - \rho_\theta^+\right)\left(\Delta - \delta - C''\left(\rho_\theta^+\right)\right)(\Delta - 2\delta)}{C''\left(\rho_\theta^+\right) C''\left(\rho_\theta^-\right) - (\Delta - \delta)\left(\Delta - \delta - \theta\left(\Delta - 2\delta\right)\right)} < 0,$$

where from $A\,(i)$ the denominator is positive, and given $A\,(iii)$ (which yields $\rho_\theta^+ < 1$), the numerator is negative. However, the probability that both firms innovate also decreases with θ:

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

The overall effect on the probability of innovation is therefore:

$$\frac{d\varrho_\theta}{d\theta} = \frac{\left(\left(1 - \rho_\theta^-\right)(\Delta - \delta) - \left(1 - \rho_\theta^+\right) C''\left(\rho_\theta^+\right)\right)\left(1 - \rho_\theta^+\right)(\Delta - 2\delta)}{C''\left(\rho_\theta^+\right) C''\left(\rho_\theta^-\right) - (\Delta - \delta)\left(\Delta - \delta - \theta\left(\Delta - 2\delta\right)\right)}.$$

This expression is negative for small values of θ since, for $\theta = 0$, $\rho^+ = \rho^- = \rho^*$ and thus:

$$\left.\frac{d\varrho_\theta}{d\theta}\right|_{\theta=0} = \frac{\left(\Delta - \delta - C''\left(\rho^*\right)\right)\left(1 - \rho^*\right)^2 (\Delta - 2\delta)}{C''\left(\rho^*\right) C''\left(\rho^*\right) - (\Delta - \delta)\left(\Delta - \delta - \theta\left(\Delta - 2\delta\right)\right)} < 0.$$

It then follows that, for low 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, as illustrated by the case of quadratic investment costs – see appendix B. ■

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. The impact on the probability of innovation is of the form $d\varrho = (1-\rho_1)\,d\rho_2 + (1-\rho_2)\,d\rho_1$: a change in one firm's investment affects the probability of innovation only 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, an increase in θ affects the probability of innovation mainly through its positive effect on the integrated firm's effort.

In order to study the impact of vertical integration on consumers and welfare, we need to specify the impact of innovation on consumers. For the sake of exposition, let us interpret our model as follows:

- the downstream firms initially produce the same good at the same cost c, and face an inelastic demand of mass M as long as their prices does not exceed consumers' valuation v;
- innovation allows the firms to produce a better product, which increases the net value $v-c$ by Δ/M.

Absent innovation, Bertrand competition yields zero profit. If instead one firm innovates, it can appropriate the full added value generated by the new product and thus obtains Δ. By contrast, when both firms innovate, Bertrand competition leads the firms to pass on the added value Δ to consumers, and thus $\delta = 0$. 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 6, 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 serve initially an inelastic demand with the same good, and that innovation uniformly increases consumers' willingness to pay by some fixed amount; then vertical integration:*

(i) always lowers consumer surplus.

(ii) always lowers total welfare when R&D costs are quadratic.

Proof. Part (i) follows from the proof of proposition 6, 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.[25] For part (ii), it suffices to note that vertical integration has no impact on innovation and welfare when $\theta = 0$ and that, for $\delta = 0$ and $C(\rho) = \frac{k}{2}\rho^2$, $W_\theta^{VI} = (\rho_\theta^+ + \rho_\theta^- - \rho_\theta^- \rho_\theta^+)\Delta - k\frac{\rho_\theta^{+2}}{2} - k\frac{\rho_\theta^{-2}}{2}$ satisfies $\frac{dW_\theta^{VI}}{d\theta} = -\frac{(\eta-1)^3\eta(\eta-1+\theta)}{(\eta^2+\theta-1)^3} < 0$. ■

The input foreclosure effect of vertical integration thus tends to harm consumers and society. In practice, however, vertical integration may also enhance welfare. For instance, vertical integration may reinforce a supplier's incentive to protect the sensitive information of its own subsidiary, in which case it may enhance welfare by fostering the innovation effort of the integrated firm.

3 Does vertical integration raise the threat of imitation?

So far, we have *postulated* that vertical integration creates a risk of information leakage and imitation. To test the validity of this assumption, we now let suppliers, integrated or not, decide whether to exploit or protect their customers' information. After all, since this information is valuable to downstream competitors, even independent suppliers may be tempted to "sell"[26] it to (some of) these competitors. As we will show, vertical integration drastically affects the ability of the firms, as well as their incentives,[27] to do so, which indeed validates our working assumption.

[25] The argument also applies to the case $\delta > 0$, implying that vertical integration reduces consumer surplus whenever an innovator fully appropriates the added value it generates if the other firm does not innovate. If for example consumers have heterogenous reservation prices – so that demand is elastic – this is the case when the innovation uniformly increases these reservation prices.

[26] 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.

[27] The recent battle between Google and Apple illustrates this concern. While they initially cooperated to bring Google's search and mapping services to Apple's iPhone, Google's entry into the mobile market led Apple to start a legal fight, claiming that HTC, a Taiwanese maker of mobile phones which uses Google's Android operating system, violates iPhone patents.

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 the 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 to not disclosing 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, $\underline{\theta} > 0$ and $(1 \geq) \overline{\theta} > \underline{\theta}$, and that opting for the low value $\underline{\theta}$ yields a private, non-transferable benefit b. It is then easier for an integrated firm to align upstream and downstream incentives in order to achieve the highest probability of successful imitation, $\overline{\theta\theta}$; as a result, vertical integration can indeed increase the likelihood of imitation. More precisely:

Proposition 8 *If $\overline{\theta} < \frac{2b}{\delta(\overline{\theta} - \underline{\theta})} \leq \overline{\theta} + \underline{\theta}$, only vertical integration allows the firms to achieve the maximal probability of successful imitation.*

Proof. See Appendix C. ■

Third, vertical integration drastically alters suppliers' incentives: while independent suppliers have incentives to maintain a good reputation, integrated suppliers may instead entertain the fear of information leakage and imitation in order to benefit from foreclosure. To see this, we now endogenize the suppliers' reliability in protecting their customers' information. A supplier can indeed affect the risk of information leakage and imitation in several ways: it may for example exacerbate this risk by investing in costly reverse-engineering technology, or attenuate it by offering guarantees, *e.g.* in the form of firewalls or compensations in case of information leakage.

To capture the intuition, we simply introduce here a preliminary stage in which suppliers publicly choose to be "reliable" or not; the game thus becomes:

- In stage 0, both suppliers, vertically integrated or not, decide (publicly and irreversibly) whether to be reliable; which option is more costly depends on the context, reverse engineering (section 3.1) or guarantees (section 3.2).

- 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 D_i, which 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 with probability $\theta > 0$.

In the next section, we dispense with the public commitment assumption (*i.e.,* stage 0) and show that the same insights apply in a dynamic framework.

3.1 Reverse engineering

We suppose here that, in stage 0, each supplier decides whether to invest publicly in a reverse engineering technology, which costs F but then allows to duplicate any innovation with probability θ. By construction, suppliers who do not invest in reverse engineering capability cannot exploit independent customers' information. Conversely, an integrated supplier can obtain at no cost the information from its subsidiary. Any supplier (integrated or not) has an incentive to exploit the information obtained from an unaffiliated customer, since doing so yields a gain δ. By contrast, an integrated supplier will never sell internal information to its rival, since the gain δ does not compensate for the resulting loss in downstream profit, $\Delta - \delta$.

An *independent* supplier will never invest in reverse engineering, as this would put its business at risk. Investing leads at best to symmetric competition (if the other supplier invests, too); it thus costs F without ever bringing any additional profit. 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:[28]

[28] The risk of opportunistic behavior highlighted by Hart and Tirole (1990) may also impede independent suppliers' ability to exploit the information acquired through reverse engineering (as they would be tempted to sell the information to all downstream rivals). By contrast, the integrated supplier does not face the same risk of opportunistic behavior and would only exploit the information internally.

Proposition 9 *Independent suppliers never invest in reverse engineering. By 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 D. ■

3.2 Guarantees

Suppliers can also provide guarantees against information leakages. They can for example offer a financial compensation in case of imitation. To be effective, such compensation must exceed δ (covering the innovator's loss in case of imitation, $\Delta - \delta$, would *e.g.* be sufficient). For example, signing a confidentiality agreement makes the supplier legally liable to some compensation; additional protection can also be offered, by increasing the amount to be paid and/or expanding the set of circumstances under which such compensation would be awarded. This however exposes the firms to potential losses arising from the uncertainty of legal proceedings, the risk of default, and so forth, and thus raises the associated transaction costs.

Alternatively, suppliers can provide non-financial guarantees such as "firewalls " – internal information barriers designed to ensure that confidential information is not passed on from one unit to another. This can for example consist in assigning distinct teams to competing customers, setting-up specific routines and procedures, adopting compliance programs prohibiting employees' communication of sensitive information, and so on. These firewalls involve costly organizational choices (*e.g.*, duplication of tasks, internal auditing teams, ...).

Our analysis shows that, while an independent supplier may choose to provide such costly guarantees in order to enhance its reputation, an integrated supplier lacks such incentive. To see this, suppose that, in stage 0, suppliers already have reverse engineering capability, but can offer guarantees at a cost φ.[29] To avoid equilibrium multiplicity issues, we introduce some upstream differentiation as in section 2.5: 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:

[29] φ corresponds here to the cost of setting-up and operating the guarantees system. In particular, in the case of financial guarantees, it does not include the stipulated compensations, since they will never be actually paid in equilibrium.

Proposition 10 *As long as the benefit from differentiation γ is not too large and the cost φ is not excessive, it is a dominant strategy for any independent supplier to offer guarantees, while an integrated supplier offers no guarantee in order to benefit from foreclosure.*

Proof. See Appendix E. ■

Consider first the case of an independent supplier facing a reliable rival. If it is unreliable, it obtains a profit (corresponding to its comparative advantage γ) only when both downstream firms innovate; by contrast, if it is reliable it obtains this profit whenever its "captive" customer innovates. Offering guarantees thus brings a benefit.

When facing instead an unreliable rival, an independent supplier – reliable or not – obtains its comparative advantage γ whenever its captive customer innovates. Becoming reliable however allows the supplier to earn an additional profit when its captive customer is the sole innovator. When the rival is independent, superior reliability moreover allows the supplier to win the competition even when its rival's captive customer is the innovator. However, this extra pressure on the rival supplier benefits its captive customer and fosters that customer's R&D efforts; by strategic substitutability, this results into lower R&D efforts by the reliable supplier's captive customer, which tends to reduce the supplier's expected profit. The overall effect on the reliable supplier's profit remains positive, however, as long as reliability matters more than the comparative advantage γ. In that case, it is a dominant strategy to offer guarantees when their cost is not excessive.

Suppose now that the integrated firm $U_A - D_1$ competes against a reliable U_B.[30] The integrated firm then supplies its own subsidiary (and protects its innovation from imitation) but never wins the competition for the independent downstream firm, who always favors the rival. Therefore, $U_A - D_1$'s variable profit is the same, whether or not it offers guarantees. Offering no guarantee however saves the cost φ and moreover increases U_B's market power over D_2, which as before reduces D_2's innovation effort. Therefore, when facing a reliable rival, the integrated supplier prefers to offer no guarantee.

[30] We show in Appendix E that D_1 is indeed better off merging with U_A rather than with the other, less favored supplier.

4 Foreclosure in a dynamic context

We now show that the above insights, derived in a static framework where the suppliers could somehow commit themselves to being reliable or not, still apply in dynamic settings without any such commitment ability. Whenever imitation creates a foreclosure effect, vertical integration drastically reduces suppliers' incentives to appear reliable.

To see this, we now consider dynamic variants of the reverse engineering model in which investments are no longer observable. We first assume that investing in reverse engineering has lasting effects. Once it has invested, the integrated firm can then demonstrate its imitation capability by exploiting its customers' information in early periods, and benefit from foreclosure in subsequent periods. Finally, to rule out any form of commitment, we consider a second variant in which in each period a supplier must invest to exploit its customers' information, and introduce reputation concerns by assuming that suppliers can be of two types, "bad" suppliers having a lower cost of imitation than "good" ones; we show that independent suppliers imitate their customers' innovation only when being bad, whereas an integrated supplier has an incentive to do so whatever its type, in order to degrade customers' perceptions and benefit from the resulting foreclosure effect.

4.1 Reverse engineering with repeated interaction

We start with the framework described in section 3.1, in which suppliers can invest F to acquire reverse engineering capability, except that investment decisions are no longer observable and take place after procurement choices; we assume instead that they have lasting effects: firms now interact over two periods and, while investment can take place at any period, once it is made reverse engineering becomes available in all (current and future) periods. In addition, duplication, and/or its impact on the innovator's profit, is observable; thus, a supplier who exploits its customer's information in the first period reveals that it is in a position to do so again in the second period. We assume $F > \delta$ and suppose that firms use a common discount factor β.

Formally, the timing of the game is as follows:

- First period ($t = 1$):

  - In a first stage, the two downstream firms simultaneously choose their investments then succeeds or fails accordingly.
  - In a second stage, the two upstream firms simultaneously offer fixed price tariffs to each downstream firm, who then selects a supplier. The selected supplier decides whether to invest in reverse engineering capability, in which case it can decipher the relevant information. Obtaining that information, either from reverse engineering or from its own subsidiary, enables the supplier to sell it (through a take-it-or-leave-it offer) to the other downstream firm.

- Second period ($t = 2$): The same two stages apply, with the caveat that any supplier who has invested in reverse engineering at $t = 1$ can decipher at no cost any customer's relevant information.

A supplier – integrated or not – who has not invested in reverse engineering in the first period does not invest in the second: it costs F, and cannot generate more than the value from duplicating the innovation, i.e. $\delta < F$. In the first period, an independent supplier does not invest either, as it would bring at most $\delta < F$ and degrade the supplier's reputation, thus wiping out any future profit.

If all firms are independent, the suppliers thus never invest in reverse engineering and, being equally reliable, supply at cost. Downstream firms' $R\&D$ investments and profits are therefore in both periods the same as in the static case: $\rho_i^t = \rho^*$ and $\pi_i^t = \pi^*$. Assume instead that U_A and D_1 have merged. In the second period, if the independent firm believes that the integrated firm has invested in reverse engineering, then foreclosure arises and benefits the integrated firm. Consider now the first period, and assume that the independent firm is the only successful innovator. If F is not too large, namely, if:

$$F - \theta\delta < \beta \left(\pi_{A1}^{VI} - \pi^* \right), \tag{16}$$

then the integrated supplier invests if selected. It is then willing to offer D_2 a subsidy reflecting not only the value from duplication in period 1, but also the foreclosure profit it would obtain in period 2. By contrast, U_B charges a positive markup, as it earns an additional profit in period 2 if its *rival*, U_A, is selected in period 1. Two cases must then be distinguished:

- When U_B wins the competition in period 1, the integrated supplier never invests in reverse engineering and foreclosure thus does not arise in period 2; however, foreclosure arises in period 1: since U_A would invest in reverse engineering if selected, U_B can charge a positive markup.

- When instead U_A wins the competition in period 1, it invests in reverse engineering; this threat generates foreclosure in period 1 – and foreclosure again arises in period 2 when D_2 is the sole innovator in period 1. In addition, compared with the case of vertical separation, the integrated firm is also less willing to invest in period 1.

Formally, we have (see appendix F for a formal analysis):

Proposition 11 *If* (16) *holds, then:*[31]

- *when* $\theta(\Delta - 2\delta) > \beta\left(\Pi^{VI} - \Pi^{VS}\right) - F$, *no firm ever invests in reverse engineering but the threat of doing so generates foreclosure in period* 1*;*

- *when* $\theta(\Delta - 2\delta) < \beta\left(\Pi^{VI} - \Pi^{VS}\right) - F$, *in period* 1 *both firms are less willing to invest in R&D than in the absence of integration, and the integrated firm moreover invests in reverse engineering when the independent rival is the sole innovator; foreclosure then arises in period* 2.

Foreclosure thus arises (either in period 1 or 2) whenever (16) holds. Repeating the interaction over $T > 2$ periods further weakens this condition, which becomes:

$$F - \theta\delta < \frac{1-\beta^T}{1-\beta}\beta\left(\pi_{A1}^{VI} - \pi^*\right). \tag{17}$$

The right-hand side increases in T, which thus relaxes the condition. In particular, if β is close enough to 1, then condition (17) is always satisfied for T large enough.

4.2 Reputation

In the previous section, investment in reverse engineering had long-lasting effects, which allowed (integrated) suppliers to "commit" themselves to being unreliable in future

[31] In the limit case $\theta(\Delta - 2\delta) = \beta\left(\Pi^{VI} - \Pi^{VS}\right) - F$, foreclosure may arise in either the first or both periods.

periods. We now consider a variant in which, in each period, suppliers must invest in order to exploit their customer's information *in that period*. We show that, even if these investment decisions are unobserved by customers, an integrated supplier has an incentive to build a reputation of exploiting its customers' information. To see this, suppose that, while some suppliers must spend an amount $F > \delta$ in order to exploit a customer's information (*e.g.*, by investing in specific reverse engineering), others can do so at no cost. We will refer to the former as "good " types and to the latter as "bad " types.[32] For the sake of exposition, we assume that only one supplier has an uncertain type: U_A, say, is good with probability p and bad with probability $1-p$, whereas U_B is good with probability 1.

We extend the two-stage game of section 2.1 by adding a last stage where suppliers, good or not, choose whether to exploit their customers' information:

- 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 independent downstream firm; each D_i then chooses its supplier.
- In stage 3, suppliers (at cost F if "good", at no cost otherwise) can sell a customer's information to its unsuccessful downstream rival, through a take-it-or-leave-it offer, in which case the rival can duplicate the innovation.

We assume that this game is played over two periods, 1 and 2, and that U_A privately learns its type in the third stage of period 1, thus after price competition but before deciding whether to exploit its customers' information.[33] All firms observe the outcomes of the R&D projects, and whether innovation eventually takes place. Thus, if only one firm has innovated and both firms launch a new product, it becomes clear that the innovator's information has been exploited. For the sake of exposition, we make the following simplifying assumptions: (i) the imitation process is perfect ($\theta = 1$); and (ii)

[32] An alternative interpretation is that exploiting confidential information exposes to prosecution; "good" types can then be interpreted as putting more weight on future profits. The following analysis corresponds formally to the case where bad types put no weight on the future, but would apply as well to situations where bad types have a significantly lower discount factor than good ones.

[33] This simplifies the analysis, by ruling out signalling issues in the first price competition stage.

the gain from duplication is "negligible": that is, we will set $\delta = 0$, but suppose that a bad supplier chooses to exploit its customer's information whenever it does not affect its future expected payoff.[34]

We show below that integration drastically affects U_A's incentive to appear reliable:[35] an independent supplier benefits from a good reputation, whereas an integrated firm prefers instead to appear as a bad supplier, in order to exacerbate the threat of imitation and benefit from the resulting strategic foreclosure effect. We only sketch the intuition here, starting with the second period before turning to the first one; the detailed analysis is presented in Appendix G.

4.2.1 Second period

Let p_A denote the updated probability that U_A is good at the beginning of period 2.

• *Price competition.* Since $\delta = 0$, profits can only be earned when a single firm, D_i, say, innovates. If D_i is vertically integrated, then its upstream unit will protect its innovation. Suppose now that D_i is independent and selects U_A. Whether U_A is integrated does not affect its reliability: since exploiting D_i's information brings only a negligible revenue, U_A does so only when it is "bad" (*i.e.*, faces no cost). $\delta = 0$ also implies that U_A obtains the same gain whatever its type; it is therefore natural to focus on pooling equilibria (both types of U_A offering the same T_A) with passive beliefs (*i.e.*, a deviating offer does not affect D_i's posterior beliefs). Price competition then amounts to a standard asymmetric Bertrand duopoly, in which U_A offers $T_A = 0$ while U_B wins with a tariff reflecting its comparative advantage, $T_B = (1 - p_A)\Delta$. In the limit case $p_A = 1$, $T_B = T_A = 0$ and we can assume that U_B still wins the competition – selecting U_A would actually be a weakly dominated strategy for D_i.

• *R&D decisions.* The expected profit of an independent D_i is equal to:

$$\Pi_i = \rho_i \left(1 - \rho_j\right) (\Delta - T_B) - C(\rho_i) = \rho_i \left(1 - \rho_j\right) p_A \Delta - C(\rho_i). \tag{18}$$

[34] Accounting for discounting or imperfect imitation is straightforward but notationally cumbersome. The extension to the case $\delta > 0$ is more involved (in particular, it requires a careful analysis of signalling issues at the price competition stage; details are available upon request).

[35] We show below that a downstream firm would indeed rather integrate with the unreliable supplier.

In the vertical separation case, the equilibrium R&D efforts are again symmetric but lower than ρ^*: $\rho_1 = \rho_2 = \hat{\rho}^*(p_A) < \rho^* = \hat{\rho}^*(1)$. Each downstream firm then obtains a profit denoted $\hat{\pi}^*(p_A)$.

If D_1 is vertically integrated with U_A, its expected profit remains given by (2). The resulting equilibrium is thus of the form $\rho_1 = \hat{\rho}^+(p_A) > \hat{\rho}^*(p_A) > \rho_2 = \hat{\rho}^-(p_A)$, characterized by the first-order conditions:

$$C'(\rho_1) = (1-\rho_2)\Delta, C'(\rho_2) = (1-\rho_1) p_A \Delta. \tag{19}$$

The resulting profits are then of the form $\pi_{A1} = \hat{\pi}^+(p_A) \geq \hat{\pi}^*(p_A)$ (with a strict inequality whenever $p_A < 1$), $\pi_2 = \hat{\pi}^-(p_A) \leq \hat{\pi}^*(p_A)$ (with a strict inequality whenever $0 < p_A < 1$), and $\hat{\pi}_B(p_A) \equiv \hat{\rho}^-(p_A)\left(1-\hat{\rho}^+(p_A)\right)(1-p_A)\Delta$ (which is positive whenever $0 < p_A < 1$, and zero otherwise). An increase in U_A's reputation fosters upstream competition and thus benefits downstream independent firms; by contrast, the integrated firm $U_A - D_1$ benefits from a reduction in p_A, since it raises its rival's cost. Indeed, we have:

Proposition 12 *In the second period, an independent U_A always obtains zero profit. All other equilibrium profits are continuous in the revised belief p_A; they coincide with the benchmark levels π^* when $p_A = 1$, and a reduction in p_A:*

(i) reduces independent downstream firms' investments and profits, down to 0 for $p_A = 0$.

(ii) benefits instead $U_A - D_1$ in case of integration, raising its investment and profit up to the monopoly level for $p_A = 0$.

Proof. See Appendix G.1. ■

4.2.2 First period

Consider now the first period. From proposition 12, under vertical separation U_A's profit in the second period does not depend on its reputation; as a result, U_A behaves as in the last period. By contrast, a vertically integrated firm *benefits* from a bad reputation. Building on this insight, we now show that, when F is not too large, it would systematically exploit D_2's information, which in turn yields *complete foreclosure* in the first period.

Vertical separation. Consider first the case of vertical separation. When either both or none downstream firm innovate(s), there is no scope for learning about U_A's type and symmetric competition yields cost-based tariffs. Suppose now that D_i is the sole innovator and selects U_A. Since U_A always obtains zero profit in the future, it then behaves as if this were the last period: if it learns that its type is bad, it chooses to sell the information; this leads to $p_A = 0$ in the second period, and thus to zero profit for all suppliers and downstream firms. If its type is good, exploiting D_i's information would cost F and bring zero profit in the second period: U_A thus refrains from doing so; this leads to $p_A = 1$ in the second period, and thus again to zero profits for both suppliers but positive expected profits, π^*, for the downstream firms.

Since U_A also obtains zero profits if not selected, it is willing to supply at cost ($\hat{T}_A = 0$), thereby giving D_i an expected profit equal to $p(\Delta + \beta\pi^*)$. This is better than what D_i would obtain by rejecting all offers, namely $\beta\hat{\pi}^*(p)\,(< p\Delta)$. However, U_B is more reliable and moreover prefers to keep U_A's type uncertain, so as to obtain $\hat{\pi}_B(p) > 0$ in the second period (it would otherwise obtain zero profit whatever the realized type: $\hat{\pi}_B(0) = \hat{\pi}_B(1) = 0$). Appendix $G.2$ shows that, as a result, U_B wins the competition but, due to the competitive pressure exerted by U_A, cannot extract all the value from the innovation. Each downstream firm then invests an amount $\hat{\rho}^{VS}(p)$, which is positive as long as $p > 0$, and obtains a total expected discounted profit of the form $\hat{\pi}^{VS}(p) + \beta\hat{\pi}^*(p)$, where $\hat{\pi}^{VS}(p) > 0$ for any $p > 0$.

Vertical integration. We now turn to the case where U_A is vertically integrated with D_1. U_A protects again the innovation of its own subsidiary, since selling D_1's information would not convey any information on U_A's type. We now study $U_A - D_1$'s decision to imitate D_2's innovation, before turning to the price competition stage; we then draw the implications for the overall equilibrium of the game.

Suppose that D_2 is the only successful innovator and has selected U_A as supplier. If U_A is bad, it duplicates D_2's innovation to entertain a bad reputation and benefit from foreclosure in period 2. For a good type, not duplicating the innovation would reveal its type and yield π^* in period 2, whereas imitating as well would keep the type uncertain

$(p_A = p)$ and thus bring $\hat{\pi}^+(p)$. As a result, when:

$$F < \hat{F}(p) \equiv \beta \left[\hat{\pi}^+(p) - \pi^*\right] > 0, \tag{20}$$

U_A always exploits D_2's information: this keeps U_A's type uncertain $(p_A = p)$ and, even for a good supplier, the associated foreclosure benefit exceeds the cost of imitation.

It follows that, when $F < \hat{F}(p)$, $U_A - D_1$ and D_2 are actually better off *not dealing with each other*: (i) the value of D_2's innovation would be dissipated via imitation; (ii) future profits are unaffected since D_2 would not learn anything about U_A's type; but (iii) by not supplying D_2, U_A avoids the risk of having to incur the cost F to maintain its (bad) reputation, in case it turns out being a good type. As a result, U_B can extract the *whole* value from D_2's innovation, Δ, and there is thus complete foreclosure. We thus have:

Proposition 13 *In the case of vertical separation, U_A obtains zero profit while both downstream firms invest a positive amount and obtain a positive expected profit in the first period. By contrast, in the case of vertical integration, if $F < \hat{F}(p)$ the integrated firm completely forecloses the market in period* 1*.*

Proof. See Appendix G.2. ■

U_A and D_1 obtain larger joint profits when they are vertically integrated, since they completely foreclose the market in period 1 (and moreover benefit from a comparative advantage in period 2, where U_A protects D_2's innovation). Note that complete foreclosure can arise even when U_A is initially perceived as quite reliable (*i.e.*, p close to 1 – the threshold $\hat{F}(p)$ however goes down to 0 as p goes to 1).

4.2.3 Lessons

Welfare implications. When F is not too large, a vertical merger between U_A and D_1 generates complete foreclosure in the first period, thereby discouraging any rival R&D investment in that period. Vertical integration however protects the integrated firm against the risk of imitation, which fosters its own incentives to invest in R&D. We now discuss the impact of these two effects on innovation and consumer surplus.

Consumer surplus in periods 1 and 2 is respectively equal to:

$$SC_1^{VI} = 0, SC_2^{VI} = \hat{\rho}^+(p)\hat{\rho}^-(p)\Delta. \tag{21}$$

In the case of vertical separation, D_2 buys from U_B in the first period, which brings no information about U_A's type. As a result, consumer surplus is equal to:

$$SC_1^{VS} = (\hat{\rho}^{VS})^2\Delta, SC_2^{VS} = \hat{\rho}^*(p)^2\Delta. \tag{22}$$

It can be checked that, in the second period, consumer surplus is higher in the case of vertical integration; this comes from the "protection" effect just mentioned: while D_2 behaves in the same way in the two scenarii (in both cases, U_B supplies D_2 with a positive tariff reflecting its comparative advantage over U_A), when vertically integrated D_1 obtains the full value Δ when it is the sole innovator, which fosters its own R&D effort as well as the probability that both firms innovate: $\hat{\rho}^+(p)\hat{\rho}^-(p) > (\hat{\rho}^*(p))^2$. However, the difference tends to disappear when p is large (since $\hat{\rho}^+(1) = \hat{\rho}^-(1) = \hat{\rho}^*(1) = \rho^*$).

By contrast, when $F < \hat{F}(p)$, then in the first period consumers obtain zero surplus in case of vertical integration, since the independent rival is then entirely foreclosed, whereas they obtain a positive surplus in the case of separation, which moreover increases with p. This yields:

Proposition 14 *As long as $F < \hat{F}(p)$, vertical integration harms consumer surplus when p is large enough.*

A similar insight applies to total welfare: when p is large, vertical integration has little impact on innovation and thus on welfare in the second period, but (as long as $F < \hat{F}(p)$) still has a drastic impact on the rival's innovation and thus on welfare in the first period.

Which merger? A related question concerns the choice of the merger partner. Suppose for example that D_1 merges instead with the more reliable supplier, U_B. In both periods, when D_2 is the sole innovator U_A is willing to supply it at cost but would exploit the information when being bad; as a result, U_B wins the competition, but investment decisions are less distorted than when D_1 merges with U_A. In particular, strategic foreclosure no longer arises in period 1.[36]

Overall, merging with U_B rather than with U_A can have an ambiguous impact on D_1's profit, since it faces a more aggressive rival but now benefits from supplying it. However, since the difference in second-period profits vanishes when p is close to 1, we have:

Proposition 15 *When p is large enough, and $F < \hat{F}(p)$, the most profitable vertical merger involves the supplier whose reputation is uncertain, so as to benefit from a larger foreclosure effect.*

Proof. See Appendix G.3. ■

The distinctive nature of imitation. Vertical integration thus indeed alters suppliers' incentives to protect their customers' information, which validates our previous working assumption that integration fosters imitation concerns. One may wonder whether a similar analysis applies to the original raising rivals' cost argument, in which the integrated firm stops supplying its rivals, or more generally degrades the conditions at which it is willing to supply them. If suppliers can take irreversible decisions (as in sections 3 and 4.1) affecting the cost or the quality of their input then an integrated firm might indeed degrade its cost or quality conditions in order to benefit from the resulting foreclosure effect. In the absence of such irreversibility, however, the reputation argument developed here for imitation concerns does not carry over to cost or quality considerations. If for example the uncertain type concerned the cost of "being unreliable" (*i.e.*, degrading quality or cost conditions),[37] then a "bad" supplier, namely, a supplier who could degrade performance at low cost, would have no incentive to do so anyway in the last periods, which defeats the reputation argument. If instead the type concerned the cost of "being reliable" (*i.e.*, having the capacity of delivering good quality at low price), an integrated firm could be tempted to pretend being unreliable, but to be consistent this would require degrading the performance of its own subsidiary, which would reduce and possibly offset the benefit from foreclosure.

[36] That is, the independent downstream rival has access to the same supply conditions as in the vertical separation case.

[37] Degrading the quality offered to rivals may for example require distinct production lines, which reduces scale economies and increases organizational costs.

5 Conclusion

This article shows that vertical integration may generate foreclosure in markets where suppliers need to exchange sensitive information with their suppliers or customers. The seminal paper by Ordover Saloner and Salop (1990) relied on two critical assumptions. First, the vertically integrated firm had to be able to commit itself to not supplying rivals, in order to give greater market power to the remaining suppliers. Second, in order to weaken downstream competition, this enhanced market power had to translate into higher input prices (as opposed to higher fixed fees or profit-based royalties, say). In our framework, foreclosure relies instead on innovation incentives and on the threat of information disclosure. Whenever vertical integration creates or exacerbates this threat, foreclosure arises even in the absence of any commitment or ex post contractual inefficiency: concerns about the integrated supplier's reliability suffice to confer market power to the other suppliers, and having to share the value of innovation with the remaining suppliers suffices to discourage rivals' R&D efforts.

We further show that vertical integration indeed drastically affects a supplier's incentive to protect or exploit its customers' innovation. Where an independent supplier has an incentive to protect its customers' innovation, so as to maintain its reputation as a reliable supplier, an integrated supplier can instead prefer to degrade its reputation, in order to enjoy the resulting strategic foreclosure benefit.

This analysis has direct implications for antitrust or merger policy. For example, even in an industry where (possibly costly) instruments exist for protecting customers' innovation (such as firewalls, compensating guarantees, and so forth), a merged entity may lack the incentives to invest in such instruments – and may instead choose to invest in (possibly costly) ways to exploit its customers' innovation. Therefore, the adoption of such protective instruments should be a prerequisite for merger clearance. Indeed, in our model no imitation happens in equilibrium, and yet the threat of information disclosure suffices to create foreclosure. Thus, an ex-post control of anticompetitive or unfair behavior would not prevent foreclosure: if protective measures are not required at the time of the merger, the integrated firm has no incentives to provide such measures and foreclosure may arise without any ex post fraudulent behavior.

While this paper emphasizes the adverse impact of vertical integration on information leaks and foreclosure, the analysis may have different implications in different industry situations. For instance, in markets where the risk of information leaks already exists even in the absence of vertical integration, a vertical merger would again exacerbate this risk for the independent rivals, but would also induce the integrated firm to better protect its own subsidiary: the overall impact of vertical integration on industry innovation, consumers, and welfare would then be more ambiguous. Also, if the upstream market is quasi-monopolized, then vertical integration and the associated foreclosure effect may well distort downstream competition in a way that reduces the merging parties' profit. This concern has for instance been mentioned in 1999 by General Motors (GM) as a motivation for spinning-off its auto parts subsidiary Delphi, so as to enable it to contract with other automakers, which were reluctant to rely on Delphi as long as it was a unit of GM.[38] A similar concern may underlie AT&T's 1995 voluntary divestiture of its manufacturing arm, AT&T Technology (now Lucent), as the coming Telecommunication Act (1996) was due to allow the RBOCs to compete with AT&T on the long distance market.[39] Finally, while we have focused on situations where information leaks intensify competition and dissipate profits, Milliou and Petrakis (2010) consider instead the case where information flows increase industry profit: that is, imitation expands demand more than it intensifies competition. The integrated firm may then choose to communicate information from its own subsidiary to the downstream rival, and vertical integration may benefit consumers as well as firms.

References

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.

Asker, J. and A. Ljungqvist (2010), "Competition and the Structure of Vertical Relationships in Capital Markets ", *Journal of Political Economy*, 118(3):599-647.

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*

[38] http://money.cnn.com/1999/05/31/companies/gm/

[39] See e..g. Hausman and Kohlberg (1989) at p. 214: "The BOCs will not want to be in a position of technological dependence on a competitor, nor will they want to discuss further service plans with the manufacturing affiliate of a competitor".

Economics, 36(3):257-265.

Chen, Y (2001), "On Vertical Mergers and Their Competitive Effects", *The RAND Journal of Economics*, 32(4):667-685.

Chen, Y. and M. H. Riordan (2007), "Vertical Integration, Exclusive dealing and Expost cartelization", *The Rand Journal of Economics*, 38(1):1-21.

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

Church, J. and N. Gandal (2000), "Systems Competition, Vertical Mergers and Foreclosure", *Journal of Economics & Management Strategy*, 9(1):25-51.

FTC (2010), *Analysis of agreement*, case nb. 0910133/100226pepsicoanal.

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.

Hausman, J. A. and E. Kohlberg (1989), "The Future Evolution of the Central Office Switch Industry", in *Future Competition in Telecommunications*, Harvard Business School Press, Bradley S. and J. Hausman, eds., 193-222.

Hughes, S. J. and L. J. Kao (2001), "Vertical integration and proprietary information transfers", *Journal of Economics and Management Strategy*, 10(2):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(2): 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(1):25-43.

Milliou, C. and E. Petrakis (2010), "Vertical Integration and Decreasing Rival's Cost", *mimeo*, may 2010.

O'Brien, D. and G. Shaffer (1992), "Vertical Control with Bilateral Contracts", *The*

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(3):698-703.

Reiffen, D. (1992), "Equilibrium Vertical Foreclosure: Comment", *The American Economic Review*, 82(3):694-697.

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

Rey, P. and J. Stiglitz, (1995), "The Role of Exclusive Territories in Producers' Competition", *The 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):120-35.

Appendix

A Productivity investments

We consider here the case of deterministic capacity investments described at the end of the section 2.5, in which each D_i obtains Cournot-like revenues of the form $\pi(\kappa_i, \kappa_j) \equiv P(\kappa_1 + \kappa_2)\kappa_i$, where $P(.)$ satisfies $P'(.) < 0$ and $P'(\kappa) + P''(\kappa)\kappa < 0$.

- When both suppliers are independent, upstream competition leads them to supply at cost; thus, each D_i chooses ρ_i so as to maximize $\pi(\rho_i, \rho_j) - C(\rho_i)$, which yields:[40]

$$P(\rho_1 + \rho_2) + P'(\rho_1 + \rho_2)\rho_i = C'(\rho_i). \tag{23}$$

  Capacity decisions are strategic substitutes and there is a unique, stable symmetric equilibrium $\rho_1 = \rho_2 = \rho^*$.[41]

- When instead U_A and D_1 are vertically integrated, U_A is willing to offer a subsidy of up to $\pi(\rho_1 + \theta\rho_2, \rho_2) - \pi(\rho_1, \rho_2)$, which would give D_2 a profit equal to:

$$\begin{aligned}\pi_2(\rho_2, \rho_1; \theta) &\equiv \pi(\rho_2, \rho_1 + \theta\rho_2) + \pi(\rho_1 + \theta\rho_2, \rho_2) - \pi(\rho_1, \rho_2) - C(\rho_2)\\ &= P(\rho_1 + (1+\theta)\rho_2)(\rho_1 + (1+\theta)\rho_2) - C(\rho_2) - P(\rho_1 + \rho_2)\rho_1.\end{aligned}$$

  As long as the total capacity $\rho = \rho_1 + \rho_2$ exceeds the level ρ^R that maximizes the joint revenue $P(\rho)\rho$, we have:

$$P(\rho_1 + (1+\theta)\rho_2)(\rho_1 + (1+\theta)\rho_2) < P(\rho_1 + \rho_2)(\rho_1 + \rho_2),$$

  which in turn implies that $\pi_2(\rho_2, \rho_1; \theta)$ is lower than $\pi(\rho_2, \rho_1) = P(\rho_1 + \rho_2)\rho_2 - C(\rho_2)$, and thus U_B wins the competition at a price that leaves D_2 with $\pi_2(\rho_2, \rho_1; \theta)$.[42]

[40] The expected profit is concave in ρ_i, since its second order derivative, $2P'(\rho_i + \rho_j) + P''(\rho_i + \rho_j)\rho_i$, is negative under the above assumptions.

[41] The slope of D_i's best response is equal to

$$\frac{\partial \rho_i^r}{\partial \rho_j} = -\frac{P'(\rho_1 + \rho_2) + P''(\rho_1 + \rho_2)\rho_i}{2P'(\rho_1 + \rho_2) + P''(\rho_1 + \rho_2)\rho_i},$$

and thus lies between -1 and 0 under the above regularity assumptions.

[42] Conversely, D_2's buying from U_B leads $U_A - D_1$ to maximize as before $\pi(\rho_1, \rho_2) = P(\rho_1, \rho_2)\rho_1$;

- Maximizing $\pi_2(\rho_2, \rho_1; \theta)$ rather than $\pi_2(\rho_2, \rho_1) = \pi_2(\rho_2, \rho_1; 0)$ leads D_2 to limit its investment, since:

$$\begin{aligned}\partial^2_{\theta\rho_2}\pi_2(\rho_2, \rho_1; \theta) &= P(\rho_1 + (1+\theta)\rho_2) + P'(\rho_1 + (1+\theta)\rho_2)(\rho_1 + (1+\theta)\rho_2) \\ &\quad + (1+\theta)^2\left[2P'(\rho_1 + (1+\theta)\rho_2) + P''(\rho_1 + (1+\theta)\rho_2)(\rho_1 + (1+\theta)\rho_2)\right],\end{aligned}$$

where the first term is negative since $\rho_1 + (1+\theta)\rho_2 > (\rho_1 + \rho_2 >)\, \rho^R$ implies that any further increase in either ρ_1 or ρ_2 reduces the joint revenue, and the second term is negative from the concavity of the joint profit function. Therefore, in equilibrium D_2 invests less than in case of vertical separation, which benefits D_1 (as it faces a less aggressive rival) and makes vertical integration profitable – in addition, since investments are strategic substitutes, D_1 invests more than in the separation case, which reduces independent rivals' joint profit.[43]

B Quadratic investment costs

We consider here the case $C(\rho) = k\rho^2/2$ (Assumption B). Straightforward computations yield:

- In case of vertical separation:

$$\rho_1^{VS} = \rho_2^{VS} = \rho^* = \frac{1}{1+\eta}, \pi_1^{VS} = \pi_2^{VS} = \pi^* = \frac{k}{2}\left(\frac{1}{1+\eta}\right)^2.$$

thus, its behavior remains characterized by the first order condition (23). When investment costs are negligible ($C(\rho) \approx 0$), $P' < 0$ and (23) imply: $P(\rho_1+\rho_2) + P'(\rho_1+\rho_2)(\rho_1+\rho_2) < P(\rho_1+\rho_2) + P'(\rho_1+\rho_2)\rho_1 = 0$, which, together with the concavity of the joint revenue function,implies that $\rho_1+\rho_2$ indeed exceeds ρ^R; by continuity, this still holds when investment costs are not too large.

[43] For example, for a linear "demand" $P(\kappa) = 1 - \kappa$ and negligible costs ($C(\rho) = 0$), the equilibrium capacities are:

$$\rho_2 = \frac{1}{3+2t} < \rho^* = \frac{1}{3} < \rho_1 = \frac{1+t}{3+2t},$$

where $t = 3\theta + 2\theta^2 > 0$, and total capacity indeed satisfies:

$$\rho_1 + \rho_2 = \frac{2+t}{3+2t} > \rho^R = \frac{1}{2}.$$

- In case of vertical integration between U_A and D_1:

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

$$\pi_{A1}^{VI} = \frac{k(\rho^+)^2}{2} = \frac{k}{2}\left(\frac{\eta-(1-\theta)}{\eta^2-(1-\theta)}\right)^2, \pi_B^{VI} + \pi_2^{VI} = \frac{k}{2}\left(1-\theta^2\right)\left(\frac{\eta-1}{\eta^2-(1-\theta)}\right)^2.$$

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 $\check{\theta}'(\eta) < 0$.

Finally, $d\varrho_\theta/d\theta \leq 0$ only for $\theta \leq \bar{\theta}(\eta) \equiv (\eta-1)^2$, where $\bar{\theta}(\eta)$ is positive and increases with η in the relevant range $\eta > 1$. As a result, partial integration reduces the overall probability of innovation if and only if $\theta < \hat{\theta}(\eta) \equiv (\eta^2-1)(\eta-1)$, where $\hat{\theta}(\eta) > \bar{\theta}(\eta)$, $\hat{\theta}'(\eta) > 0$, and $\hat{\theta}(\eta) < 1$ as long as $\eta < \hat{\eta} = \frac{1+\sqrt{5}}{2}$.

C Proof of proposition 8

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: $\overline{\theta}\overline{\theta}\phi \geq \overline{\theta}\underline{\theta}\phi + b$;
- the downstream firm does the same, that is: $\overline{\theta}\overline{\theta}(\delta-\phi) \geq \overline{\theta}\underline{\theta}(\delta-\phi) + b$.

Summing-up these two conditions, the risk of imitation can be maximal only if $\overline{\theta}\overline{\theta}\delta \geq \overline{\theta}\underline{\theta}\delta + 2b$, that is, only if:

$$\delta \geq \frac{2b}{\left(\overline{\theta}-\underline{\theta}\right)\overline{\theta}}. \tag{24}$$

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: $\overline{\theta}^2\delta \geq \overline{\theta}\underline{\theta}\delta + b$,
- none doing so, which requires: $\overline{\theta}^2\delta \geq \underline{\theta}^2\delta + 2b$.

The latter constraint is the more demanding[44] and amounts to:

$$\delta \geq \frac{2b}{\left(\overline{\theta} - \underline{\theta}\right)\left(\overline{\theta} + \underline{\theta}\right)}, \tag{25}$$

which is less demanding than (24). The conclusion follows.

D Proof of proposition 9

As already noted, no independent supplier ever invests 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); downstream firms invest $\rho_1 = \rho_2 = \rho^*$ and obtain an expected profit equal to $\Pi^* \equiv \Pi(\rho^*, \rho^*)$, whereas upstream firms make no profit.

Suppose now that U_A merges with D_1, say, whereas U_B remains independent – and thus chooses to be reliable. As already noted in the text, the integrated firm never provides internal information to its independent rival. 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 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 suppliers, Bertrand competition drives again tariffs to zero. Expected downstream profits are thus again $\Pi_i\left(\rho_i, \rho_j\right)$ and both investments are equal to ρ^*. $U_A - D_1$'s expected profit is thus still equal to Π^*.

- If instead $U_A - D_1$ is an unreliable supplier, it offers D_2 a subsidy of up to $T_{A2} = -\theta\delta$ but U_B wins by charging $T_{B2} = \theta(\Delta - 2\delta)$. The expected profits of the investing firms are then respectively $\Pi_{A1} = \Pi(\rho_1, \rho_2)$ and $\Pi_2 = \Pi_\theta(\rho_2, \rho_1)$. The equilibrium investments are thus $\rho_1 = \rho_\theta^+ > \rho^* > \rho_2 = \rho_\theta^-$, and $U_A - D_1$'s expected profit is $\Pi_\theta^+ > \Pi^*$.

$U_A - D_1$ therefore invests in reverse engineering whenever $F < \Pi_\theta^+ - \Pi^*$.

[44] 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 $\overline{\theta} > \underline{\theta}$.

E Proof of proposition 10

As mentioned in Section 3.2, we assume here that firm D_1 (resp. D_2) obtains a small surplus γ (in case of innovation) when buying from its favored supplier U_A (resp. U_B).

Suppliers' reliability is irrelevant when both downstream firms' innovation efforts are successful. In that case, asymmetric Bertrand competition leads D_i's favored supplier to win the competition with a tariff appropriating the surplus γ: letting "f" designate the favored supplier and "n" refer to the other, non-favored supplier, U_n offers D_i a tariff $T_n = 0$, but U_f wins with a tariff (slightly below) $T_f = \gamma$. 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 always protects 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, and only D_i innovates, then asymmetric Bertrand competition leads D_i's favored supplier to win with a tariff reflecting its comparative advantage; D_i thus obtains Δ while its favored supplier obtains γ. Each D_i's expected profit is therefore given by $\Pi_i = \Pi\left(\rho_i, \rho_j\right)$, and equilibrium investments are thus $\rho_1 = \rho_2 = \rho^*$. Since suppliers obtain γ whenever the downstream firm that favors them innovates, their equilibrium expected profits are both equal to:

$$\Pi_{rr}^{VS} \equiv \rho^* \gamma.$$

• Suppose now that both suppliers are unreliable, and that D_i is the only successful innovator. Asymmetric Bertrand competition leads the non-favored supplier, U_n, to offer $T_n = -\theta\delta$, while the favored supplier wins with $T_f = \gamma - \theta\delta$, and then sells (at "full" price $\theta\delta$) the information to the downstream rival, who duplicates the innovation with probability θ. Thus, D_i obtains

$$\theta\delta + (1-\theta)\Delta + \gamma - T_f = \theta\delta + (1-\theta)\Delta - T_n = \Delta - \theta(\Delta - 2\delta),$$

while its favored supplier obtains $T_f + \theta\delta = \gamma$.

Ex ante, each D_i's expected profit is thus $\Pi_i = \Pi_\theta\left(\rho_i, \rho_j\right)$. Both best responses are thus of the form $\rho_i = R_\theta\left(\rho_j\right) < R\left(\rho_j\right)$, and equilibrium investments are symmetric: $\rho_1 = \rho_2 = \rho_\theta^* < \rho^*$. Suppliers' equilibrium expected profits are thus lower than before and now equal to

$$\Pi_{uu}^{VS} \equiv \rho_\theta^* \gamma.$$

• 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 $\gamma < \theta\left(\Delta - 2\delta\right)$), then when D_i is the only successful innovator Bertrand competition results in U_A offering $T_{Ai} = -\theta\delta$ 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 $T_{B1} = \theta\left(\Delta - 2\delta\right) - \gamma$ and D_1 obtains $\Delta - \theta\left(\Delta - 2\delta\right) + \gamma$; when instead D_2 is the only successful innovator, then charges U_B $T_{B2} = \theta\left(\Delta - 2\delta\right) + \gamma$ and D_2 obtains $\Delta - \theta\left(\Delta - 2\delta\right)$. The expected profits of the two downstream firms are thus respectively:

$$\begin{aligned}\Pi_1 &= \Pi_\theta^\gamma\left(\rho_1, \rho_2\right) \equiv \rho_1\left(\rho_2\delta + \left(1 - \rho_2\right)\left(\Delta - \theta\left(\Delta - 2\delta\right) + \gamma\right)\right) - C\left(\rho_1\right) \\ &= \Pi_\theta\left(\rho_2, \rho_1\right) + \rho_1\left(1 - \rho_2\right)\gamma,\end{aligned}$$

and

$$\Pi_2 = \Pi_\theta\left(\rho_2, \rho_1\right).$$

Best responses are therefore of the form $\rho_2 = R_\theta\left(\rho_1\right)$ and $\rho_1 = R_\theta^\gamma\left(\rho_2\right)$, where $R_\theta^\gamma\left(\rho_2\right)$ is characterized by the first-order condition

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

and thus satisfies $R_\theta\left(\rho\right) < R_\theta^\gamma\left(\rho\right) < R\left(\rho\right)$. Note that D_1 benefits from U_B's superior reliability, as it forces its favorite supplier, U_A, to concede better terms (that is, U_A gives back γ). As a result, equilibrium investments are asymmetric and such that $\rho_1 = \tilde{\rho}^+ > \rho_\theta^* > \rho_2 = \tilde{\rho}^-$: U_B's superior reliability actually *reduces* its captive customer's R&D effort, since its rival, D_1, who benefits from U_B's competitive pressure on U_A, becomes more aggressive.

Since U_A now obtains a profit only when both downstream firms innovate, its expected profit becomes:

$$\Pi_A = \Pi_{ur}^{VS} \equiv \tilde{\rho}^- \tilde{\rho}^+ \gamma,$$

whereas U_B's expected profit is equal to:

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

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

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

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

$$\Pi_{ru}^{VS} > \tilde{\rho}^+ \gamma > \rho_\theta^* \gamma = \Pi_{uu}^{VS}.$$

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

$$\Pi_{uu}^{VS} < \Pi_{ru}^{VS} \text{ and } \Pi_{ur}^{VS} < \Pi_{rr}^{VS}.$$

This, in turn, implies that providing guarantees constitutes a dominant strategy whenever $\varphi < \varphi^{VS} \equiv \min\left\{\Pi_{rr}^{VS} - \Pi_{ur}^{VS}, \Pi_{ru}^{VS} - \Pi_{uu}^{VS}\right\}$.

Vertical integration.

Suppose now that U_A merges with D_1, which protects D_1 against imitation and moreover allows it to internalize the full value of its innovation.

- If the independent supplier is at least as reliable as the integrated supplier (that is, both suppliers are reliable, both are unreliable, or U_A is unreliable whereas U_B is reliable), then $U_A - D_1$'s expected profit is equal to:[45]

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

[45]Note that D_1 does not make any additional profit when U_B is unreliable and only D_2 innovates, since U_B then sells the information at its full value $\theta\delta$.

The corresponding best response, $\rho_1 = R^\gamma(\rho_2)$, is characterized by the first-order condition:

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

It thus satisfies $R^\gamma(\rho) > R(\rho)$, $R^\gamma(0) > 0$, and:

$$0 > R^{\gamma\prime}(\rho) = \frac{-(\Delta-\delta)}{C''(R^\gamma(\rho))} > -1.$$

D_2's expected profit is equal to $\Pi(\rho_2,\rho_1)$ if both suppliers are reliable, and to $\Pi_\theta(\rho_2,\rho_1)$ if the integrated firm is not reliable;[46] therefore:

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

$$\Pi_B = \Pi^{VI}_{rr} \equiv \rho^{\gamma-}\gamma.$$

- If instead U_A is not reliable, D_2's best response is given by $\rho_2 = R_\theta(\rho_1)$ and we will denote by $\left(\rho_\theta^{\gamma+},\rho_\theta^{\gamma-}\right)$ the resulting equilibrium investments; simple comparative statics yield $\rho_\theta^{\gamma-} < \rho^{\gamma-} < \rho^*$ and $\rho_\theta^{\gamma+} > \rho^{\gamma+} > \rho^*$. 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:

$$\Pi_B = \Pi^{VI}_{uu} \equiv \rho_\theta^{\gamma-}\gamma.$$

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

$$\Pi_B = \Pi^{VI}_{ru} \equiv \rho_\theta^{\gamma-}\left(\gamma + \left(1-\rho_\theta^{\gamma+}\right)\theta(\Delta-2\delta)\right).$$

- *If* the integrated supplier is more reliable than its independent rival, *then* when D_2

[46] D_2 obtains δ if both downstream firms innovate. If it is the sole innovator, it obtains Δ if both suppliers are reliable. If U_A is not reliable, then U_B extracts its comparative advantage (γ if it is unreliable, and $\gamma + \theta(\Delta-2\delta)$ otherwise) and leave only $\Delta - \theta(\Delta-2\delta)$ to D_2.

is the sole innovator U_B offers $T_{B2} = -\theta\delta$ but $U_A - D_1$ wins by offering $T_{A2} = \theta(\Delta - 2\delta) - \gamma$; the expected profits of the two investing firms are then equal to $\Pi_2 = \Pi_\theta^\gamma(\rho_2, \rho_1)$ and:

$$\Pi_{A1} = \mathring{\Pi}(\rho_1, \rho_2) \equiv \Pi^\gamma(\rho_1, \rho_2) + (1 - \rho_1)\rho_2(\theta(\Delta - 2\delta) - \gamma).$$

D_2's best response is thus $\rho_2 = R_\theta^\gamma(\rho_1)$, whereas $U_A - D_1$'s best response is of the form $\rho_1 = \mathring{R}(\rho_2)$, characterized by the first-order condition:

$$\begin{aligned} C'(\rho_1) &= \rho_2\delta + (1 - \rho_2)\Delta + \gamma - \rho_2(\theta(\Delta - 2\delta) - \gamma) \\ &= \rho_2(\delta - (\theta(\Delta - 2\delta) - \gamma)) + (1 - \rho_2)\Delta + \gamma. \end{aligned}$$

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

$$\Pi_B = \Pi_{ur}^{VI} \equiv \mathring{\rho}_1\mathring{\rho}_2\gamma.$$

• Let us now study the reliability decisions. If $U_A - D_1$ chooses not to be reliable, then as long as $\rho_\theta^{\gamma-} > 0$ (that is, as long as there is only partial foreclosure, or $\theta < 1$), U_B benefits from being reliable, since this increases its expected profit from Π_{uu}^{VI} to $\Pi_{ru}^{VI} = \Pi_{uu}^{VI} + \rho_\theta^{\gamma-}\left(1 - \rho_\theta^{\gamma+}\right)\theta(\Delta - 2\delta) > \Pi_{uu}^{VI}$. If instead $U_A - D_1$ chooses to be reliable, U_B's net gain from reliability is equal to:

$$\Pi_{rr}^{VI} - \Pi_{ur}^{VI} = \left(\rho^{\gamma-} - \mathring{\rho}_1\mathring{\rho}_2\right)\gamma.$$

When γ tends to zero, $\rho^{\gamma-}$ converges to ρ_θ^*, solution to $\rho = R_\theta(\rho)$, whereas $(\mathring{\rho}_1, \mathring{\rho}_2)$ tends to $\left(\mathring{\rho}_1^0, \mathring{\rho}_2^0\right)$, which in particular satisfies $\rho_2 = R_\theta(\rho_1)$. In the limit, the difference $\rho^{\gamma-} - \mathring{\rho}_1\mathring{\rho}_2$ thus converges to $\rho_\theta^* - \mathring{\rho}_1^0.\mathring{\rho}_2^0$, which is positive: since both $(\rho_\theta^*, \rho_\theta^*)$ and $\left(\mathring{\rho}_1^0, \mathring{\rho}_2^0\right)$ lie on the best response $\rho_2 = R_\theta(\rho_1)$, which has a negative slope, ρ_θ^* is greater than either $\mathring{\rho}_1^0$ or $\mathring{\rho}_2^0$, and thus (since moreover $\mathring{\rho}_i^0 \leq 1$) exceeds their product. Therefore, there exists γ^{VI} such that $\Pi_{rr}^{VI} - \Pi_{ur}^{VI} > 0$ as long as $\gamma < \gamma^{VI}$. In this range, it is a dominant strategy for the independent supplier to offer guarantees as long as $\varphi < \varphi^{VI} \equiv \min\left\{\Pi_{rr}^{VI} - \Pi_{ur}^{VI}, \Pi_{ru}^{VI} - \Pi_{uu}^{VI}\right\}$.

Consider now the reliability decision of the integrated firm, when facing a reliable rival. Being reliable yields an expected profit equal to $\Pi^\gamma(\rho^{\gamma+}, \rho^{\gamma-}) - \varphi$, whereas being unreliable yields:

$$\Pi^{\gamma}\left(\rho_{\theta}^{\gamma+}, \rho_{\theta}^{\gamma-}\right) = \max_{\rho_1} \Pi^{\gamma}\left(\rho_1, \rho_{\theta}^{\gamma-}\right) > \max_{\rho_1} \Pi^{\gamma}\left(\rho_1, \rho^{\gamma-}\right) = \Pi^{\gamma}\left(\rho^{\gamma+}, \rho^{\gamma-}\right),$$

where the inequality stems from $\rho_{\theta}^{\gamma-} < \rho^{\gamma-}$. It follows that it is best for $U_A - D_1$ to be unreliable (by denying guarantees), so as to benefit from the foreclosure effect.

To recap:

- when $\gamma < \min\left\{\gamma^{VS}, \gamma^{VI}\right\}$, it is always a dominant strategy for an independent supplier to provide guarantees as long as the cost of doing so does not exceed $\min\left\{\varphi^{VS}, \varphi^{VI}\right\}$).
- by contrast, when facing a reliable independent supplier, an integrated firm finds it optimal to appear unreliable by denying guarantees.

Which merger? We now check that D_1 prefers indeed to merge with its favorite supplier U_A rather than with U_B. Assume instead that D_1 and U_B have merged; depending on the reliability decisions of the suppliers we need to consider four cases:

1. Both U_A and U_B are reliable:

$$\Pi_{B1} = \Pi(\rho_1, \rho_2) + \rho_2\gamma, \Pi_2 = \Pi(\rho_1, \rho_2),$$

and the equilibrium investments are thus $\rho_1 = \rho_2 = \rho^*$.[47] U_A's profit is therefore $\Pi_A = \Pi_{rr}^{VI} = \rho^*\gamma$.

2. U_A is reliable and U_B is unreliable:

$$\Pi_{B1} = \hat{\Pi}^{\gamma}(\rho_1, \rho_2) \equiv \Pi(\rho_1, \rho_2) + \rho_1\rho_2\gamma, \Pi_2 = \Pi_{\theta}^{\gamma}(\rho_2, \rho_1) = \Pi_{\theta}(\rho_2, \rho_1) + \rho_2(1 - \rho_1)\gamma.$$

Investment behaviors are thus of the form $\rho_1 = \hat{R}^{\gamma}(\rho_2) \in [R(\rho_2), R^{\gamma}(\rho_2)]$ (with $\hat{R}^{\gamma}(\rho) > R(\rho)$ whenever $\rho > 0$) and $\rho_2 = \hat{R}_{\theta}(\rho_1) \in [R_{\theta}(\rho_1), R(\rho_1)]$ (with $R(\rho) <$

[47] Since ρ_2 affects Π_{B1} in an additive separable way, it does not affect D_1's innovation behavior, which remains given by $\rho_1 = R(\rho_2)$.

$\hat{R}_\theta(\rho) < R_\theta(\rho)$ whenever $\rho < 1$); the resulting equilibrium investments are thus of the form $\rho_1 = \hat{\rho}_\theta^{\gamma+}$ and $\rho_2 = \hat{\rho}_\theta^{\gamma-}$, where

$$\rho_\theta^{\gamma-} < \hat{\rho}_\theta^{\gamma-} < \rho^* < \hat{\rho}_\theta^{\gamma+} < \rho_\theta^{\gamma+}. \quad (26)$$

U_A's profit is then $\Pi_A = \Pi_{ru}^{VI} = \hat{\rho}_\theta^{\gamma+}\gamma + \hat{\rho}_\theta^{\gamma-}(1 - \hat{\rho}_\theta^{\gamma+})[\theta(\Delta - 2\delta) - \gamma]$.

3. Both U_A and U_B are unreliable:

$$\Pi_{B1} = \Pi(\rho_1, \rho_2) + \rho_2\gamma, \Pi_2 = \Pi_\theta(\rho_2, \rho_1).$$

The best responses are thus $\rho_1 = R(\rho_2)$ and $\rho_2 = R_\theta(\rho_1)$, and the resulting equilibrium investments are $\rho_1 = \rho_\theta^+$ and $\rho_2 = \rho_\theta^-$. Supplier A's profit is therefore $\Pi_A = \Pi_{uu}^{VI} = \rho_\theta^+\rho_\theta^-\gamma$.

4. U_A is unreliable and U_B is reliable:

$$\Pi_{B1} = \breve{\Pi}(\rho_1, \rho_2) \equiv \Pi(\rho_1, \rho_2) + \rho_2\gamma + \rho_2(1 - \rho_1)\theta(\Delta - 2\delta), \Pi_2 = \Pi_\theta(\rho_2, \rho_1).$$

We will denote by $\rho_1 = \breve{\rho}_\theta^+$ and $\rho_2 = \breve{\rho}_\theta^-$ the resulting equilibrium investments, characterized by the best responses $\rho_2 = R_\theta(\rho_1)$ and $\rho_1 = \breve{R}(\rho_2)$, where $\breve{R}(\rho_2) < R(\rho_1)$. Supplier A's profit is then $\Pi_A = \Pi_{ur}^{VI} = \breve{\rho}_\theta^+\breve{\rho}_\theta^-\gamma$.

It is first easy to check that, whatever $U_B - D_1$'s reliability, U_A strictly prefers to be reliable:

- If $U_B - D_1$ is reliable, U_A obtains $\rho^*\gamma$ if reliable and $\Pi_{ur}^{VI} = \breve{\rho}_\theta^+\breve{\rho}_\theta^-\gamma$ if unreliable; but since the best responses $R_\theta(.)$ and $\breve{R}(.)$ have a negative slope and are both lower than $R(.)$, it follows that $\breve{\rho}_\theta^-\breve{\rho}_\theta^+ < \rho^*$.[48] Thus, U_A chooses to be reliable.
- When facing an unreliable $U_B - D_1$, U_A obtains $\Pi_A = \Pi_{uu}^{VI} = \rho_\theta^+\rho_\theta^-\gamma$ if unreliable and $\Pi_{ru}^{VI} = \hat{\rho}_\theta^{\gamma+}\gamma + \hat{\rho}_\theta^{\gamma-}(1 - \hat{\rho}_\theta^{\gamma+})[\theta(\Delta - 2\delta) - \gamma]$ if reliable. Since

$$\Pi_{ru}^{VI} > \hat{\rho}_\theta^{\gamma+}\gamma > \rho^*\gamma > \rho_\theta^-\gamma > \Pi_{uu}^{VI},$$

[48] This is obvious if $\breve{\rho}_\theta^-$ and $\breve{\rho}_\theta^+$ are both lower than ρ^*; if instead one – ρ_i, say – exceeds ρ^*, than the other one satisfies $\rho_j = R_j(\rho_i) < R_j(\rho^*) < R(\rho^*) = \rho^*$.

U_A again prefers being reliable.

Second, whatever $U_B - D_1$'s reliability, its profit is always lower than the foreclosure profit D_1 would obtain by merging with U_A, $\Pi^\gamma(\rho_\theta^{\gamma+}, \rho_\theta^{\gamma-})$:

- If $U_B - D_1$ is reliable, its profit is $\Pi(\rho^*, \rho^*) + \rho^*\gamma = \Pi^\gamma(\rho^*, \rho^*)$ and $\rho_\theta^{\gamma-} < \rho^*$ implies:

$$\Pi^\gamma(\rho^*, \rho^*) < \max_{\rho_1} \Pi^\gamma(\rho_1, \rho^*) < \max_{\rho_1} \Pi^\gamma(\rho_1, \rho_\theta^{\gamma-}) = \Pi^\gamma(\rho_\theta^{\gamma+}, \rho_\theta^{\gamma-}).$$

- If $U_B - D_1$ is instead unreliable, its profit is: $\hat{\Pi}^\gamma(\hat{\rho}_\theta^{\gamma+}, \hat{\rho}_\theta^{\gamma-})$, and:

$$\hat{\Pi}^\gamma(\hat{\rho}_\theta^{\gamma+}, \hat{\rho}_\theta^{\gamma-}) = \max_{\rho_1} \hat{\Pi}^\gamma(\rho_1, \hat{\rho}_\theta^{\gamma-}) < \max_{\rho_1} \Pi^\gamma(\rho_1, \hat{\rho}_\theta^{\gamma-}) < \max_{\rho_1} \Pi^\gamma(\rho_1, \rho_\theta^{\gamma-}) = \Pi^\gamma(\rho_\theta^{\gamma+}, \rho_\theta^{\gamma-}),$$

  where the last inequality stems from $\hat{\rho}_\theta^{\gamma-} > \rho_\theta^{\gamma-}$.

F Reverse engineering with repeated interaction: vertical integration

Assume that U_A and D_1 have merged, and first consider the second period competition stage. As already noted, the integrated firm protects its own subsidiary even if it has already invested in reverse engineering; and since the independent U_B never invests in reverse engineering, it never exploits any customer's information. However, D_2's procurement decision (when being the sole innovator) depends on its beliefs about the integrated supplier's ability to exploit its innovation. If D_2 believes that U_A did not invest in reverse engineering in the first period (and correctly anticipates that U_A never invests in the second period), then upstream competition remains symmetric, among reliable suppliers; thus, in the second period suppliers price at cost, whereas downstream firms invest $\rho_i^2 = \rho^*$ and expect to obtain $\pi_i^2 = \pi^*$.

Suppose instead that D_2, being the sole innovator, believes that U_A previously invested in reverse engineering. Assuming passive beliefs,[49] asymmetric upstream competition then leads U_A to offer a discount $-\theta\delta$ and U_B to win with a positive tariff

[49] That is, assuming that D_2 does not revise its belief when receiving an out-of-equilibrium offer in period 2.

reflecting its comparative advantage, thus giving D_2 the same expected profit as U_A's offer. The expected profits of the investing firms are therefore: $\pi_{A1}^2 = \pi_1^2 = \Pi(\rho_1, \rho_2)$ and $\pi_2^2 = \Pi_\theta(\rho_1, \rho_2)$. A foreclosure effect thus arises and, as a result, in the second period the investments are $\rho_1^2 = \rho_\theta^+ > \rho^*$ and $\rho_2^2 = \rho_\theta^- < \rho^*$, and the profits become:

$$\pi_{A1}^2 = \pi_{A1}^{VI} > \pi^*, \pi_2^2 = \pi_2^{VI} < \pi^*, \text{ and } \pi_B^{VI} = \rho_\theta^- \left(1 - \rho_\theta^+\right) \theta \left(\Delta - 2\delta\right).$$

Consider now the first period. When both firms innovate, or none of them does, upstream competition is symmetric and leads the suppliers to supply at cost. The two firms obtain δ in the former case and 0 in the latter case, and in both cases no supplier has an incentive to invest in reverse engineering (U_B never invests anyway, and U_A would not be able to demonstrate its capacity to imitate D_2's innovation). By contrast, U_A may be tempted to invest in reverse engineering when selected by a downstream firm that is the sole innovator; more precisely:

- If the innovator is D_1, U_A cannot benefit from investing in reverse engineering: even if it wants to sell its subsidiary's innovation, it is cheaper to simply obtain it from D_1; therefore, selling the information will not be interpreted as "having invested in reverse engineering ", which in turn implies that it is not worth selling it (it only brings δ and reduces downstream profit by $\Delta - \delta > \delta$).

- If the innovator is D_2, investing in reverse engineering entails a net loss $F - \theta\delta$ at $t = 1$, but gives U_B extra market power at $t = 2$ and thus increases the profit of the integrated firm in the second period by $\pi_{A1}^{VI} - \pi^*$; therefore, under condition (16), the integrated supplier will invest in reverse engineering if selected by the downstream rival.

Thus, under (16), when D_2 is the only innovator at $t = 1$, it will anticipate that selecting the integrated supplier will lead it to invest in reverse engineering. U_B thus benefits from a comparative advantage over U_A; however, U_A is willing to offer a discounted tariff, $\hat{T}_A$, reflecting not only the value from duplication in period 1, but also the additional profit it would obtain in period 2 if selected in period 1 and investing in reverse engineering:

$$\hat{T}_A = F - \theta\delta - \beta\left(\pi_{A1}^{VI} - \pi^*\right) < 0.$$

By contrast, the best tariff that U_B is willing to offer, $\hat{T}_B$, takes into account the additional profit it could achieve in period 2 if its rival, U_A, is instead selected in period 1, and is thus such that:

$$\hat{T}_B = \beta \pi_B^{VI} > 0.$$

Finally, U_B wins the competition when its best offer dominates:

$$\Delta - \hat{T}_B + \beta \pi^* > \Delta - \theta (\Delta - \delta) + \beta \pi_2^{VI} - \hat{T}_A,$$

which amounts to:

$$\theta (\Delta - 2\delta) > \beta \left(\Pi^{VI} - \Pi^{VS} \right) - F,$$

where

$$\Pi^{VI} - \Pi^{VS} = \pi_{A1}^{VI} + \pi_2^{VI} + \pi_B^{VI} - 2\pi^*.$$

denotes the impact of foreclosure on total industry profit. This condition thus amounts to saying that the industry loss resulting from duplication in period 1 exceeds the increase in profit (if any) resulting from foreclosure in period 2 (in particular, it is satisfied whenever foreclosure reduces industry profit).

G Reputation

G.1 Proof of Proposition 12

G.1.1 Vertical separation

Given the outcome of price competition, in the case of vertical separation each D_i's expected profit is equal to:

$$\Pi_i = \rho_i \left(1 - \rho_j \right) p_A \Delta - C (\rho_i) . \tag{27}$$

The resulting equilibrium R&D efforts are symmetric but lower than ρ^*:

$$\rho_1 = \rho_2 = \hat{\rho}^* (p_A) < \rho^* = \hat{\rho}^* (1) . \tag{28}$$

The equilibrium profits are then

$$\begin{aligned}
\pi_1 &= \pi_2 = \hat{\pi}^*(p_A) \equiv \hat{\rho}^*(p_A)(1-\hat{\rho}^*(p_A))p_A\Delta - C(\hat{\rho}^*(p_A)), \\
\pi_A &= 0, \\
\pi_B &= 2\hat{\rho}^*(p_A)(1-\hat{\rho}^*(p_A))(1-p_A)\Delta.
\end{aligned}$$

Note that the equilibrium profits increase with p_A. Indeed, the envelope theorem yields:

$$\hat{\pi}^{*\prime}(p_A) = \hat{\rho}^*(p_A)(1-\hat{\rho}^*(p_A))\Delta - \hat{\rho}^*(p_A)\hat{\rho}^{*\prime}(p_A)p_A\Delta,$$

while differentiating the first-order condition $C'(\hat{\rho}^*(p_A)) = (1-\hat{\rho}^*(p_A))p_A\Delta$ yields:

$$\hat{\rho}^{*\prime}(p_A) = \frac{(1-\hat{\rho}^*(p_A))\Delta}{C''(\hat{\rho}^*) + p_A\Delta}\,(>0).$$

Therefore:

$$\hat{\pi}^{*\prime}(p_A) = \frac{\hat{\rho}^*(p_A)(1-\hat{\rho}^*(p_A))\Delta C''(\hat{\rho}^*(p_A))}{C''(\hat{\rho}^*(p_A)) + p_A\Delta} > 0. \tag{29}$$

Therefore, as p_A increases from 0 to 1, the equilibrium profits increase from $\hat{\pi}^*(0) = 0$ to $\hat{\pi}^*(1) = \pi^*$.

G.1.2 Vertical integration

If U_A is vertically integrated with D_1, the equilibrium profits are then of the form $\pi_{A1} = \hat{\pi}^+(p_A)$, $\pi_2 = \hat{\pi}^-(p_A)$, and $\pi_B = \hat{\rho}^-(p_A)\left(1-\hat{\rho}^+(p_A)\right)(1-p_A)\Delta$. In particular, the effort and the profit of the vertically integrated firm increase as its perceived quality, p_A, decreases; indeed, as p_A decreases from 1 to 0:

- $\hat{\rho}^-(p_A)$ decreases from the symmetric competitive level ρ^* to 0 ;
- $\hat{\rho}^+(p_A)$ therefore increases ρ^* to ρ^m, the monopoly level satisfying $C'(\rho^m) = \Delta$;
- as a result, $\hat{\pi}^+(p_A)$ increases from the competitive level π^* to the monopoly level, $\pi^m = \max_\rho \rho\Delta - C(\rho)$.

G.2 Proof of Proposition 13

We consider in turn the separation and integration cases.

G.2.1 Vertical separation

Suppose that D_i, being the sole innovator, selects U_A as an independent supplier. U_A then behaves as if this were the last period, since it obtains zero future profit anyway; it thus exploits D_i's innovation only when learning that it is of a bad type. The expected gross profits of D_i, U_A and U_B are therefore respectively equal to:

$$\begin{aligned}
\pi_i^A &\equiv (1-p) \times 0 + p(\Delta + \beta\pi^*) = p(\Delta + \beta\pi^*), \\
\pi_A^A &\equiv 0, \\
\pi_B^A &\equiv 0 + \beta\left[p \times \hat{\pi}_B(1) + (1-p) \times \hat{\pi}_B(0)\right] = 0,
\end{aligned}$$

where the superscript A denotes the selected supplier. Since U_A also obtains zero profits if not selected, it is willing to supply at cost ($\hat{T}_A = 0$), which would give D_i an expected profit equal to:

$$\hat{\pi}_i^A = \pi_i^A - \hat{T}_A = p(\Delta + \beta\pi^*).$$

This is better than what D_i would obtain by rejecting all offers, namely $\beta\hat{\pi}^*(p) = \beta\left[\hat{\rho}^*(p)(1-\hat{\rho}^*(p))p\Delta - C(\hat{\rho}^*)\right] < p\Delta$.

If instead D_i selects U_B, then these expected profits depend on the prior belief (which remains unchanged for the second period) and become respectively:

$$\begin{aligned}
\pi_i^B &\equiv \Delta + \beta\hat{\pi}^*(p), \\
\pi_A^B &\equiv 0, \\
\pi_B^B &\equiv 0 + 2\hat{\rho}^*(p)(1-\hat{\rho}^*(p))(1-p)\beta\Delta = 2\hat{\rho}^*(p)(1-\hat{\rho}^*(p))(1-p)\beta\Delta.
\end{aligned}$$

In the price competition stage, U_B is thus willing to offer up to:

$$\hat{T}_B \equiv -\left(\pi_B^B - \pi_B^A\right) = -2\hat{\rho}^*(p)(1-\hat{\rho}^*(p))(1-p)\beta\Delta < 0,$$

which would give D_i an expected profit equal to:

$$\hat{\pi}_i^B \equiv \pi_i^B - \hat{T}_B = \Delta + \beta\left[\hat{\pi}^*(p) + 2\hat{\rho}^*(p)(1-\hat{\rho}^*(p))(1-p)\Delta\right].$$

This best offer beats U_A's one, since:

$$\begin{aligned}\hat{\pi}_i^B - \hat{\pi}_i^A &= \Delta + \beta\left[\hat{\pi}^*(p) + 2\hat{\rho}^*(p)(1-\hat{\rho}^*(p))(1-p)\Delta\right] - p(\Delta + \beta\pi^*) \\ &\geq \phi(p) \equiv (1-p)\Delta + \beta\left[\hat{\pi}^*(p) - p\pi^*\right],\end{aligned}$$

where $\phi(p) > 0$ for $p < 1$, since $\phi(1) = 0$ and, using (29):

$$\phi'(p) = -\Delta\left(1 - \beta\hat{\rho}^*(1-\hat{\rho}^*)\frac{C''(\hat{\rho}^*)}{C''(\hat{\rho}^*) + p\Delta}\right) - \beta\pi^* < 0.$$

Therefore, U_B wins the competition, by offering a tariff that gives D_i the same expected profit as $\hat{\pi}_i^A = p(\Delta + \beta\pi^*)$. Ex ante, each D_i's expected profit is therefore equal to:

$$\begin{aligned}\pi_i &= \rho_i(1-\rho_j)\hat{\pi}_i^A + (1-\rho_i(1-\rho_j))(0 + \beta\hat{\pi}^*(p)) - C(\rho_i) \\ &= \beta\hat{\pi}^*(p) + \rho_i(1-\rho_j)\left[p\Delta + \beta(p\pi^* - \hat{\pi}^*(p))\right] - C(\rho_i).\end{aligned}$$

It follows that the R&D equilibrium is symmetric:

$$\rho_1 = \rho_2 = \hat{\rho}^{VS}(p),$$

characterized by the first-order condition:

$$C'(\rho) = (1-\rho)\left[p\Delta + \beta(p\pi^* - \hat{\pi}^*(p))\right].$$

$\hat{\rho}^{VS}(p)$ moreover strictly increases from 0 to ρ^* as p increases from 0 to 1:

$$\frac{d\hat{\rho}^{VS}}{dp} = \frac{\left(1-\hat{\rho}^{VS}\right)\left[\Delta + \beta\left(\pi^* - \hat{\pi}^{*\prime}(p)\right)\right]}{C''\left(\hat{\rho}^{VS}\right) + p\Delta + \beta\left[p\pi^* - \hat{\pi}^*(p)\right]},$$

where the numerator is positive since:

$$\beta\hat{\pi}^{*\prime}(p) = \beta\hat{\rho}^*(1-\hat{\rho}^*)\frac{C''(\hat{\rho}^*)}{C''(\hat{\rho}^*) + p\Delta}\Delta < \Delta, \qquad (30)$$

whereas the denominator is also positive since $\beta\hat{\pi}^*(p) < p\Delta$. Each downstream firm then obtains a total expected discounted profit equal to $\hat{\pi}^{VS}(p) + \beta\hat{\pi}^*(p)$, where:

$$\hat{\pi}^{VS}(p) \equiv \hat{\rho}^{VS}(1-\hat{\rho}^{VS})\left[p\Delta + \beta\left(p\pi^* - \hat{\pi}^*(p)\right)\right] - C(\hat{\rho}^{VS}).$$

G.2.2 Vertical integration

First, when U_A is vertically integrated with D_1, U_A always protects the innovation of its own downstream division D_1: selling the innovation to D_2 would reduce the first period profit (from Δ to 0) and, since the integrated firm has direct access to D_1's information, would not convey any relevant information on U_A's ability to exploit D_2's innovation in period 2. If instead D_2 is the only successful innovator and selects U_A, we have:

Lemma 16 *When $F < \hat{F}(p)$, if D_2 is the sole innovator and selects U_A, then the integrated firm imitates D_2's innovation, whatever U_A's type.*

Proof. Consider a candidate equilibrium in which $U_A - D_1$ imitates D_2's innovation with probability μ_b when it is bad, and with probability μ_g when it is good. If $\mu_g > \mu_b$, imitating enhances the reputation of the firm: in the second period, D_2's updated belief, p_A^i, satisfies

$$p_A^i \equiv \frac{p\mu_g}{p\mu_g + (1-p)\mu_b} > p.$$

By contrast, by not imitating D_2's innovation, the integrated firm would strategically benefit from a downgraded reputation in the second period: D_2's updated belief, p_A^n, would then satisfy

$$p_A^n \equiv \frac{p\left(1-\mu_g\right)}{p\left(1-\mu_g\right) + (1-p)\left(1-\mu_b\right)} < p.$$

Since the expected continuation profit $\hat{\pi}^+(p_A)$ increases as p_A decreases, a good firm would rather not imitate, as this moreover saves the cost F, contradicting the initial assumption $\mu_g > \mu_b$. We can thus suppose $\mu_g \leq \mu_b$, which in turn implies $p_A^n \geq p \geq p_A^i$. Imitating cost nothing to a bad firm and, by downgrading the reputation of the firm, can only increase its expected profit in the second period. Therefore, according to our tie-breaking assumption, a bad firm chooses to imitate D_2's innovation. We thus have $\mu_g \leq \mu_b = 1$, which implies

$$p_A^i = \frac{p\mu_g}{p\mu_g + 1 - p} \leq p.$$

Imitating then costs F to a good firm but increases second-period profits from $\hat{\pi}^{+}(1) = \pi^*$ to $\hat{\pi}^{+}(p_A^i) \geq \hat{\pi}^{+}(p)$. Therefore, as long as $F < \hat{F}(p)$, even a good integrated firm chooses to imitate D_2's innovation $\left(\mu_g = \mu_b = 1\right)$: the integrated firm always imitates D_2's innovation, whatever U_A's type, leading to unchanged beliefs in the second period: $p_A^i = p$. ■

Thus, if $F < \hat{F}(p)$, then if D_2 selects U_A the expected profits of $U_A - D_1$, D_2 and U_B are respectively equal to:

$$\begin{aligned} \pi_{A1}^A &\equiv -pF + \beta\hat{\pi}^{+}(p), \\ \pi_2^A &\equiv 0 + \beta\hat{\pi}^{-}(p) = \beta\hat{\pi}^{-}(p), \\ \pi_B^A &\equiv 0 + \beta\hat{\rho}^{-}(p)\left(1 - \hat{\rho}^{+}(p)\right)(1-p)\Delta = \beta\hat{\rho}^{-}(p)\left(1 - \hat{\rho}^{+}(p)\right)(1-p)\Delta. \end{aligned}$$

If D_2 was to reject all offers, it would obtain the same profit $\beta\hat{\pi}^{-}(p)$, whereas $U_A - D_1$ would obtain $\beta\hat{\pi}^{+}(p)$ and thus save the expected cost pF that it may have to face it if it turns out to be of a good type. Therefore, D_2 and $U_A - D_1$ are better off not dealing with each other. By contrast, D_2 and U_B can together generate an extra profit Δ. Thus, U_B wins the competition but, since D_2's second-best option is to reject all offers, U_B extracts all the value from D_2's innovation, by offering a tariff $T_B = \Delta$.

It follows that D_2 never invests in the first period, and thus $U_A - D_1$ benefits from a monopoly position in that period; it thus maximizes:

$$\pi_{A1} = \rho_1\Delta - C(\rho_1) + \beta\hat{\pi}^{+}(p),$$

and chooses the investment level ρ^m.

Compared with the case of vertical separation, whenever $p < 1$, U_A and D_1 joint profit increases in the second period, from $\hat{\pi}^*(p)$ to $\hat{\pi}^{+}(p)$, and it also increases in the first period, since:

$$\begin{aligned} \hat{\pi}^{VS}(p) &= \max_{\rho} \rho(1 - \hat{\rho}^{VS})\left[p\Delta + \beta\left(p\pi^* - \hat{\pi}^*(p)\right)\right] - C(\rho) \\ &< \max_{\rho} \rho\left[p\Delta + \beta\left(p\pi^* - \hat{\pi}^*(p)\right)\right] - C(\rho) \\ &< \max_{\rho} \rho\Delta - C(\rho) = \pi^m, \end{aligned}$$

where the last inequality stems from (using (30)):

$$\frac{d\left(p\Delta+\beta\left(p\pi^{*}-\hat{\pi}^{*}(p)\right)\right)}{dp}=\Delta+\beta\left(\pi^{*}-\hat{\pi}^{*\prime}(p)\right)>0,$$

and:

$$p\Delta+\beta\left(p\pi^{*}-\hat{\pi}^{*}(p)\right)\big|_{p=1}=\Delta.$$

G.3 Proof of Proposition 15

We study here the equilibrium when D_1 merges with U_B. In the second period, the investment levels, $\rho_1=\tilde{\rho}^{+}(p_A)$ and $\rho_2=\tilde{\rho}^{-}(p_A)$, are characterized by the following first-order conditions:

$$C'(\rho_1)=(1-\rho_2(2-p_A))\Delta, C'(\rho_2)=(1-\rho_1)p_A\Delta, \tag{31}$$

and the resulting expected profits are:

$$\begin{aligned}\pi_{B1} &= \tilde{\pi}^{+}(p_A)\equiv\tilde{\rho}^{+}(p_A)(1-\tilde{\rho}^{-}(p_A))\Delta+(1-\tilde{\rho}^{+}(p_A))\tilde{\rho}^{-}(p_A)(1-p_A)\Delta-C(\tilde{\rho}^{+}(p_A)),\\ \pi_2 &= \tilde{\pi}^{-}(p_A)\equiv\tilde{\rho}^{-}(p_A)(1-\tilde{\rho}^{+}(p_A))p_A\Delta-C(\tilde{\rho}^{-}(p_A)).\end{aligned}$$

As noted in the text, we have $\tilde{\rho}^{+}(p_A)<\hat{\rho}^{+}(p_A)$, $\hat{\rho}^{-}(p_A)>\tilde{\rho}^{-}(p_A)$, and $\tilde{\pi}^{-}(p_A)>\hat{\pi}^{-}(p_A)$. In addition, the outcome coincides with the benchmark case (ρ^{*} and π^{*}) for $p_A=1$ and with the monopoly case ($\rho_1=\rho^{m},\rho_2=0$ and $\pi_{B1}=\pi^{m},\pi_2=0$) for $p_A=0$.

Let us now turn to the first period, and suppose that D_2 is the sole innovator. Selecting U_A would lead it to exploit D_2's innovation only when being bad. The expected profits of U_A, D_2 and U_B-D_1 are then:

$$\pi_A^A=0,\pi_2^A=p(\Delta+\beta\pi^{*}),\pi_{B1}^A=\beta\left[p\pi^{*}+(1-p)\pi^{m}\right].$$

If instead D_2 selects U_B, these expected profits become:

$$\pi_A^B=0,\pi_2^B=\Delta+\beta\tilde{\pi}^{-}(p),\pi_{B1}^B=\beta\tilde{\pi}^{+}(p).$$

Suppliers thus are ready to offer up to:

$$\tilde{T}_A = -(\pi_A^A - \pi_A^B) = 0, \tilde{T}_B = -(\pi_{B1}^B - \pi_{B1}^A) = \beta \left[p\pi^* + (1-p)\pi^m - \tilde{\pi}^+(p) \right],$$

which would give D_2 expected profits equal to:

$$\tilde{\pi}_2^A = p(\Delta + \beta\pi^*), \tilde{\pi}_2^B = \Delta + \beta \left[\tilde{\pi}^-(p) + \tilde{\pi}^+(p) - p\pi^* - (1-p)\pi^m \right].$$

The latter is likely to be higher;[50] in particular, we have:

Lemma 17 *$\tilde{\pi}_2^B > \tilde{\pi}_2^A$ when p is close to 1.*

Proof. To see this, define

$$\psi(p) \equiv \tilde{\pi}_2^B - \tilde{\pi}_2^A = (1-p)\Delta + \beta \left[\tilde{\pi}^-(p) + \tilde{\pi}^+(p) - 2p\pi^* - (1-p)\pi^m \right],$$

and note that $\psi(1) = 0$ and:

$$\psi'(p) = -(\Delta - \beta\pi^m) + \beta \left[\frac{d(\tilde{\pi}^+ + \tilde{\pi}^-)}{dp} - 2\pi^* \right] < \beta \frac{d(\tilde{\pi}^+ + \tilde{\pi}^-)}{dp}.$$

Furthermore, differentiating the first-order conditions (31) yields:

$$\begin{aligned} \tilde{\rho}^{+\prime}(1) &= \frac{\rho^* C''(\rho^*) - (1-\rho^*)\Delta}{(C''(\rho^*))^2 - \Delta^2}\Delta, \\ \tilde{\rho}^{-\prime}(1) &= \frac{(1-\rho^*) C''(\rho^*) - \rho^*\Delta}{(C''(\rho^*))^2 - \Delta^2}\Delta, \end{aligned}$$

and thus (using $C'(\rho^*) = (1-\rho^*)\Delta$):

$$\begin{aligned} \left. \frac{d(\tilde{\pi}^+ + \tilde{\pi}^-)}{dp} \right|_{p=1} &= -(1-\rho^*)\rho^*\Delta - \rho^*\Delta\tilde{\rho}^{-\prime}(1) + (1-\rho^*)\rho^*\Delta - \rho^*\Delta\tilde{\rho}^{+\prime}(1) \\ &= -\rho^*\Delta \frac{C''(\rho^*) - \Delta}{(C''(\rho^*))^2 - \Delta^2}\Delta \\ &= \frac{-\rho^*\Delta^2}{C''(\rho^*) + \Delta} < 0. \end{aligned}$$

[50] It can for example be shown that this is always the case when $C''(.) > 2\Delta$. This is also the case when p is close to 0, since then $\tilde{\pi}_2^B = \Delta > \tilde{\pi}_2^A = 0$.

The conclusion then follows, since $\psi(1) = 0$ and $\psi'(1) < 0$ imply $\tilde{\pi}_2^B > \tilde{\pi}_2^A$ for p smaller than but close to 1. ■

Whenever $\tilde{\pi}_2^B > \tilde{\pi}_2^A$, U_B wins the competition with a tariff T_B that leaves D_2 indifferent between accepting that or U_A's best offer, namely, such that:

$$T_B = \Delta + \beta\tilde{\pi}^-(p) - p(\Delta + \beta\pi^*) = (1-p)\,\Delta + \beta\left(\tilde{\pi}^-(p) - p\pi^*\right).$$

Therefore, investing firms' total expected discounted profits become:

$$\begin{aligned}
\pi_{B1} &= \rho_1(1-\rho_2)\Delta + (1-\rho_1)\rho_2\left[(1-p)\,\Delta + \beta\left(\tilde{\pi}^-(p) - p\pi^*\right)\right] - C(\rho_1) + \beta\tilde{\pi}^+, \\
\pi_2 &= \rho_2(1-\rho_1)\left[p\Delta + \beta\left(p\pi^* - \tilde{\pi}^-(p)\right)\right] - C(\rho_2) + \beta\tilde{\pi}^-(p).
\end{aligned}$$

The corresponding investment levels are thus characterized by the following first-order conditions:

$$\begin{aligned}
C'(\rho_1) &= (1-(2-p)\,\rho_2)\,\Delta - \rho_2\beta\left(\tilde{\pi}^-(p) - p\pi^*\right), \\
C'(\rho_2) &= (1-\rho_1)\left[p\Delta + \beta\left(p\pi^* - \tilde{\pi}^-(p)\right)\right].
\end{aligned}$$

These investment levels converge respectively to ρ^* when p tends to 1, and in the limit the integrated firm simply obtains π^* in each period.

By contrast, when D_1 merges with U_A, as long as $F < \hat{F}(p)$, their joint profit is equal to $\pi^m + \hat{\pi}^+(p)$, which tends to $\pi^m + \pi^*$ as p tends to 1. Since U_A moreover obtains zero profit when remaining independent, integrating U_A is more profitable than integrating U_B when p is close to 1.