

# Vertical Integration, Information and Foreclosure<sup>1</sup>

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## **Abstract**

This paper studies the impact of vertical integration on competition and performance in markets where firms need to exchange sensitive information in order to interact efficiently with their suppliers or customers. We show that, by altering a supplier's incentives to protect or exploit its customers' information, vertical integration degrades the supplier's ability to interact with downstream competitors. In case of limited competition upstream, this leads to input foreclosure, raises rivals' cost and limits both upstream competition and downstream development. A similar concern of customer foreclosure arises in the case of downstream bottlenecks.

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# 1 Introduction

This paper shows that vertical integration can harm competitors by fostering the risk of information leakages. The successful development of a business project often requires the exchange of sensitive information with suppliers and customers, which creates a risk of information dissemination. As we will see, vertical integration exacerbates this risk. For example, an integrated supplier can be more tempted to pass on such information to its own 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 and “raises rivals’ costs”, impeding their development.<sup>1</sup> A similar concern of customer foreclosure arises in the case of downstream bottlenecks.<sup>2</sup>

This issue arises for instance in corporate finance; as shown by Asker and Ljungqvist (2010), the fear of information leakages induces competing firms to refrain from sharing the same investment bank.<sup>3</sup> The issue has also been raised in a number of vertical mergers,<sup>4</sup> and stressed by the European Commission 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.”<sup>5</sup>

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<sup>1</sup>For an early discussion of “raising rivals’ costs” strategies, see Krattenmaker and Salop (1986).

<sup>2</sup>Brand manufacturers have for example stressed such issues 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 are concerned that it gives these retailers an opportunity to reduce or even eliminate the lead time before the apparition of “me-too” private labels.

<sup>3</sup>The sale in 2003 of the Israeli supermarket chain Blue Square provides another illustration. The Alon group was competing with another potential buyer, Paz, in which one of the main banks (Leumi) was holding a 20% share. In a recent conference, Alon’s CEO, Dudi Weisman, complained that information concerns prevented it from obtaining financing from Leumi, leaving it in the hands of the other main bank (Hapoalim). See <http://www.presidentconf.org.il/en/indexNew.asp> (we thank Yossi Spiegel for bringing this example to our attention).

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

<sup>5</sup>*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.

This concern is particularly serious for innovative industries, where information disclosure can foster imitation. A recent European example is the merger between TomTom, a leading manufacturer of portable navigation devices (or “PNDs”), and Tele Atlas, one of the two main providers of digital map databases for navigation in Europe and North America. In its decision,<sup>6</sup> the European Commission stresses the importance of information exchanges: “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.”<sup>7</sup> The Commission then notes that third parties feared that “certain categories of information [...] could, after the merger, be shared with TomTom”, which “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”.<sup>8</sup>

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 servicing its rival Dr Pepper Snapple (henceforth “DPSG”). The FTC expressed the 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

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<sup>6</sup>Case No COMP/M.4854 - TOMTOM/TELE ATLAS, 14/05/2008.

<sup>7</sup>Commission decision at § 256. For a discussion of strategic information disclosure in bargaining situations, see Crocker (1983).

<sup>8</sup>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).

competitor [...]”.<sup>9</sup> The FTC ordered PepsiCo to set up a firewall in order to regulate the use of this commercially sensitive information.<sup>10</sup> Similar concerns arose in the smartphones market, following the announced acquisition of Motorola’s phone division by Google, developer of the Android system software – leaving independent smartphone makers with a single independent software supplier (Microsoft).<sup>11</sup>

Our analysis supports these concerns. We consider a bilateral duopoly framework in which, to develop an innovation, firms must share with their suppliers some information, which cannot be protected by traditional intellectual property rights. We first show that vertical integration leads indeed to foreclosure when it exacerbates a risk of imitation through information leakages. By making the supplier less “reliable”, vertical integration confers market power to the alternative supplier and allows it to appropriate part of the value of the downstream competitor’s innovation. This, in turn, discourages the rival’s innovation efforts and increases the merging parties’ profit at the expense of independent rivals – even if these can “fight back” and integrate as well. We also show that foreclosure harms consumers and reduces total welfare. Finally, while for the sake of exposition we use a simple duopoly setting and cast our analysis in terms of R&D investments and imitation concerns, we check that the insights carry over to more general settings as well as to other types of investment and information concerns.

We then discuss several reasons why an integrated firm may indeed be more likely to exploit its 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 a successful imitation. But vertical integration also fosters the merged entity’s incentives to exploit customers’ information; that is, strategic motives exacerbate the risk of imitation. An integrated firm may for example choose

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<sup>9</sup>See FTC 2010; The FTC was also concerned by the risk of facilitated coordination in the industry.

<sup>10</sup>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).

<sup>11</sup>Andy Lees, president of the Microsoft Windows Phone Division, promptly seized the opportunity, stating on August 15, 2011 that “Windows Phone is now the only platform [...] with equal opportunity for all partners”, while market analysts predicted a likely switch of independent phone makers from Android to Windows Phone: “Google is in the business of supplying software to hardware makers, and buying one of those hardware makers isn’t going to endear them to the rest of their customers”, said Charles Golvin, a Forrester Research analyst in a Wall Street Journal article (available at <http://online.wsj.com/article/SB10001424053111903392904576509953821437960.html>).

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 to 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 first relates to the literature on 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 this way the market power of alternative suppliers.<sup>12</sup> 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.<sup>13</sup> 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.<sup>14</sup> In case of

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<sup>12</sup>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.

<sup>13</sup>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).

<sup>14</sup>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.

vertical separation, the downstream industry is competitive and prices reflect 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 it 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 in order to depreciate that product. 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 supplier, so that even though the integrated firm wishes to keep supplying its rivals, the rivals become less keen to do so.<sup>15</sup>

Our paper also relates 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, which reduces both the value of a patent and the extent 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

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<sup>15</sup>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.

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 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 ability nor its incentives to innovate. A firewall would however eliminate the adverse impact on rivals' R&D incentives and 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 framework where firms can commit – either directly or indirectly – to being reliable or not (section 3), and then in a reputation 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 is indeed the case 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.<sup>16</sup> 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  $T$ .<sup>17</sup>

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  $\delta < \Delta/2$ .<sup>18</sup> 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”:

$D_1 \backslash D_2$	$I$	$N$	
$I$	$\delta, \delta$	$\Delta, 0$	(1)
$N$	$0, \Delta$	$0, 0$	

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

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

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

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

<sup>16</sup>The risk of information leakages also provides a motivation for single sourcing.

<sup>17</sup>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).

<sup>18</sup>Suppose for instance that the innovation creates a new product. If only one firm innovates, it obtains a monopoly profit,  $\pi^M$ ; if instead both firms innovate, they share a lower duopoly profit  $\pi^D < \pi^M$ . We then have  $\Delta = \pi^M$  and  $\delta = \pi^D/2 < \Delta/2$ .

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

- In stage 1,  $D_1$  and  $D_2$  simultaneously choose their  $R\&D$  efforts and then innovate with probabilities  $\rho_1$  and  $\rho_2$ ; 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 consider later a variant of this game where  $U_A$  is vertically integrated with  $D_1$ , which creates a risk of information leakage:  $D_1$  can then imitate  $D_2$ 's innovation with probability  $\theta$  if  $D_2$  chooses  $U_A$  as supplier.

## 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  $\rho_i$  so as to maximize its expected profit, given by:

$$\pi_i = \Pi(\rho_i, \rho_j) \equiv \rho_i(\rho_j\delta + (1 - \rho_j)\Delta) - C(\rho_i). \quad (2)$$

It follows that  $R\&D$  efforts are strategic substitutes:

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

Let  $\rho_i = R(\rho_j)$  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:

$$C'(\rho_i) = \rho_j\delta + (1 - \rho_j)\Delta, \quad (4)$$

and that it yields a unique equilibrium,<sup>19</sup> which is symmetric, interior and stable:<sup>20</sup>

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<sup>19</sup>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.

<sup>20</sup>That is, the slope of the best responses is lower than 1 in absolute value.

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

$$0 \leq R(\rho) < 1, \quad (5)$$

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

$$-1 < R'(\rho) < 0. \quad (6)$$

*As a result there exists a unique equilibrium, which is symmetric and such that:*

$$0 < \rho_1 = \rho_2 = \rho^* < 1. \quad (7)$$

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

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

Since  $R(0) > 0$  and  $R(1) < 1$ , there is thus a unique  $\rho^*$  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.

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The resulting profits under vertical separation are thus  $\pi_A^{VS} = \pi_B^{VS} = 0$  and  $\pi_1^{VS} = \pi_2^{VS} = \pi^* \equiv \Pi(\rho^*, \rho^*) > 0$ .

### 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  $\theta$  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<sup>21</sup> 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:

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

$R_\theta(\cdot)$  coincides with  $R(\cdot)$  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  $\theta$  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:*

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

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

**Proof.** When  $\theta = 1$  and  $\delta = 0$ ,  $R_\theta(\cdot) = 0$ ; 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 is uniquely characterized by the first-order condition (9) and satisfies  $0 \leq R_\theta(\rho) < 1$ , with  $R_\theta(\rho) > 0$  whenever  $\rho < 1$ . Differentiating (9) yields:

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

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<sup>21</sup>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  $U_B$ .

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

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

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

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

■

In what follows, we denote by  $\pi_{A1}^{VI} \equiv \Pi(\rho_\theta^+, \rho_\theta^-)$  the equilibrium profit of the integrated firm, by  $\pi_2^{VI} \equiv \Pi_\theta(\rho_\theta^-, \rho_\theta^+)$  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.<sup>22</sup> 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  $\theta$ . 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,

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<sup>22</sup>The analysis is the same when upstream firms are “pure developers”, needed only when an R&D project succeeds.

when the imitation concern is maximal ( $\theta = 1$  and  $\delta = 0$ ), the integrated supplier is of 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** *Vertical integration yields input foreclosure:*

(i) *it leads the independent firm to invest less, and the integrated subsidiary to invest more in R&D – all the more so as the probability of imitation,  $\theta$ , 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  $\rho_\theta^-$  and  $\rho_\theta^+$  respectively decrease and increase as  $\theta$  increases, and that they both coincide with  $\rho^*$  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:

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

and:

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

where the first inequality stems from the fact that  $\rho_\theta^-$  is chosen by  $D_2$  so as to maximize its own profit,  $\Pi_\theta(\rho_2, \rho_\theta^+)$ , rather than the joint profit  $\Pi(\rho_2, \rho_\theta^+)$  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.<sup>23</sup>

## 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  $\theta^S$  to  $\theta^I > \theta^S$ . The distortion term  $\theta(\Delta - 2\delta)$  then simply becomes  $(\theta^I - \theta^S)(\Delta - 2\delta)$ .

*Number of upstream and downstream 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 degrading the perceived quality of the integrated supplier creates or reinforces market power among the remaining independent suppliers.

*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  $\rho_1 = \rho_2 = \rho^*$ . By contrast, in case of vertical integration the independent supplier obtains a share  $\lambda$  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:

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

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<sup>23</sup>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.

The same analysis then applies, replacing  $\theta$  with the “adjusted probability”  $\lambda\theta$ , which now depends on the relative bargaining power of the supplier as well as on the risk of imitation.

*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,  $T_{B2} = \theta L > 0$ .

*Business stealing.* More generally, the analysis applies whenever the integrated firm could appropriate sensitive information about business strategies, as long as doing so destroys part of the industry profit. Suppose for instance that, whenever  $D_2$  comes up with an innovative strategy (and  $D_1$  does not), the integrated firm can “steal” the idea, which results in profits  $\alpha_1\Delta$  for  $D_1$  and  $\alpha_2\Delta$  for  $D_2$ , where  $\alpha = \alpha_1 + \alpha_2 < 1$ ; then, while the integrated firm is willing to offer a subsidy of  $-\alpha_1\Delta$ , its opportunistic behavior still generates a foreclosure effect, by reducing  $D_2$ ’s profit by  $(1 - \alpha)\Delta > 0$ .

*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  $\delta$ . Yet, partial foreclosure still arises as long as imitation reduces total industry profit ( $\Delta > 2\delta$ ).

*Imperfect competition in the upstream market and voluntary divestitures.* The above reasoning carries over to the case where suppliers symmetrically differentiated, so that each downstream firm has a favored supplier:  $D_1$  (resp.  $D_2$ ) obtains an additional surplus  $\gamma$  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.<sup>24</sup>

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<sup>24</sup>For a formal derivation, see Allain, Chambolle and Rey (2011), Appendix E.



When instead one of the supplier benefits from a substantial comparative advantage over its rival, and thus enjoys market power in the upstream segment, vertical integration may no longer be profitable: while the downstream subsidiary still benefits from the resulting foreclosure, the upstream division is prevented from fully exerting its market power. The resulting balance of the conflicting impacts on upstream and downstream profits may in that case lead the firms to favor separation. Suppose for example that *both* downstream firms get an additional surplus  $\hat{\gamma}$  when they develop an innovation with  $U_A$ . Under vertical separation,  $U_A$  always wins the (asymmetric) Bertrand competition and supplies any downstream innovator with a tariff  $T_A = \hat{\gamma}$ . As a result, each  $D_i$ 's expected profit remains the same as before, while  $U_A$  now obtains  $(\rho_1 + \rho_2)\hat{\gamma}$ . Thus, while downstream firms still invest  $\rho_1 = \rho_2 = \rho^*$ ,  $U_A$ 's equilibrium expected profit becomes  $2\rho^*\hat{\gamma}$ , which increases with  $\hat{\gamma}$ . When instead  $U_A$  and  $D_1$  are integrated,  $U_A$  can still charge  $T_A = \hat{\gamma}$  to  $D_2$  when both firms innovate, but when  $D_2$  is the sole innovator  $U_B$  now wins the upstream competition with a tariff  $T_{B2} = \theta(\Delta - 2\delta) - (1 + \theta)\hat{\gamma}$  as long as  $\hat{\gamma}$  is not too large (namely, as long as this tariff remains positive – otherwise,  $U_A$  wins and foreclosure does not arise). As a result,  $D_2$  is foreclosed (its expected profit is reduced by  $T_{B2}$ ), but  $U_A$  loses the profit  $\hat{\gamma}$  when  $D_2$  happens to be the sole innovator (thus with probability  $\rho_2(1 - \rho_1)$ ); as a result, and despite the foreclosure effect of vertical integration, vertical separation is more profitable when  $\hat{\gamma}$  is not too small.<sup>25</sup>

*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 could be avoided if suppliers could commit themselves before

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<sup>25</sup>For example, if  $\hat{\gamma}$  is smaller than, but close to  $\frac{\theta(\Delta - 2\delta)}{(1 + \theta)}$ , vertical separation is more profitable despite the foreclosure benefit of vertical integration. A formal analysis is available upon request.

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  $\delta = 0$  and  $\theta = 1$ , where *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  $\rho_1(\cdot)$  and  $\rho_2(\cdot)$  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 rival manufacturers’ innovation.<sup>26</sup>

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<sup>26</sup>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*,

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  $\rho_A$  and  $\rho_B$  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 the same 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 and expansion projects.* 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 information exchanges with upstream or downstream partners. Suppose for example that:

- Downstream competition depends on firms’ “effective capacities”,  $\kappa_1$  and  $\kappa_2$ : 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  $P'(\cdot) < 0$  and  $P'(\kappa) + P''(\kappa)\kappa < 0$ , implying that capacities are strategic substitutes.
- Each  $\kappa_i$  depends on  $D_i$ ’s investment decision,  $\rho_i$ , 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,  $\rho_1$  and  $\rho_2$ , 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

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Eine Studie für den Markenverband (DIW Econ)).

at cost; the above regularity conditions imply 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, as shown in appendix A, 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  $\Pi^*$ ; 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, as just discussed, 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.<sup>27</sup>

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:

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

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<sup>27</sup>This discussion applies for example to the TomTom/TeleAtlas and Nokia/Navteq mergers, if GPS handheld devices (TomTom) and smartphones (Nokia) are considered as good substitutes. Otherwise, our base case scenario applies as the mergers confers market power to Navteq over TomTom's rivals and to TeleAtlas over Nokia's rivals.

The interval  $[\underline{K}, \overline{K}]$  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  $[\underline{K}, \overline{K}]$  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 imitation fully dissipates profit and R&D costs follow a standard quadratic specification:

**Assumption B:**

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

Assumption A then boils down to:

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

We have:

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

**Proof.** 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).<sup>28</sup> When innovation efforts are inexpensive (namely,  $\eta < 2$ ), the firms would actually find it optimal to have *one* firm (and only one) invest  $\frac{1}{\eta}$  ( $> \frac{1}{2}$ ), so as to avoid the competition that

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<sup>28</sup>These R&D efforts thus maximize a joint profit equal to:  $(\rho_1(1 - \rho_2) + \rho_2(1 - \rho_1))\Delta - k\rho_1^2/2 - k\rho_2^2/2$ .

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.*  $\eta$  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,

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

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  $\varrho$  when  $\theta$  is not too large, but can increase it for larger values of  $\theta$ . 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  $\theta$  increases:

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

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  $\theta$ :

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

The overall effect on the probability of innovation is therefore:

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

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

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

It then follows that, for low values of  $\theta$ , partial integration decreases the probability of innovation (that is,  $\varrho_{\theta} < \varrho^{*} = \varrho_0$ ). For larger values of  $\theta$ , 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  $\theta$  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  $\theta$  is close to zero), the effect of an increase in  $\theta$  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  $\theta$  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 a unit inelastic demand as long as their prices does not exceed consumers' valuation  $v$ ;
- innovation creates a better product, which increases the net surplus  $v - c$  by  $\Delta$ .

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  $\Delta$ . By contrast, when both firms innovate, Bertrand competition leads the firms to pass on the added value  $\Delta$  to consumers, and thus  $\delta = 0$ . The (expected) consumer surplus  $S$  and total welfare  $W$  are then:

$$S \equiv \rho_1 \rho_2 \Delta,$$

$$W \equiv (\rho_1 + \rho_2 - \rho_1 \rho_2) \Delta - C(\rho_1) - C(\rho_2).$$

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,<sup>29</sup> which shows that the probability that both firms innovate under partial integration decreases with  $\theta$ , and coincides for  $\theta = 0$  with that obtained with vertical separation. For part (ii), it suffices to note that vertical integration has no impact on innovation and welfare when  $\theta = 0$  and that, 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.<sup>30</sup>

<sup>29</sup>The argument thus also applies to any  $\delta < \Delta/2$ .

<sup>30</sup>In a related paper, Choi (1998) considers the case where vertical integration allows the firm to conceal cost information that was previously public.



To see this, consider a variant of our model where the risk of information leakage and imitation exists even with independent suppliers, and characterized by a probability  $\hat{\theta}$ . Vertical integration between  $U_A$  and  $D_1$  raises the probability of information leakage to  $\theta^+ \geq \hat{\theta}$  for  $D_2$  if it buys from  $U_A$  (and remains equal to  $\hat{\theta}$  otherwise), but reduces it to  $\theta^- \leq \hat{\theta}$  for  $U_A - D_1$ . In this framework, the increased risk for the independent firm (from  $\hat{\theta}$  to  $\theta^+$ ) has a negative effect on consumer surplus and, in the case of quadratic costs, it also lowers welfare. The reduction in the integrated firm’s risk of imitation may however compensate for this loss. Yet this “bright side” has an ambiguous impact on surplus and welfare. In particular, a decrease in  $\theta^-$  (i) reduces the likelihood of “accidental” leakages for given  $R\&D$  efforts; and (ii) can also reduce the probability  $\rho_1\rho_2$  that both firms innovate simultaneously; these two effects tend to lower consumer surplus. Overall, the combination of the “bright” and “dark” sides of vertical integration can either increase or decrease consumer surplus and welfare.<sup>31</sup>

### 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”<sup>32</sup> it to (some of) these competitors. As we will show, vertical integration drastically affects the ability of the firms, as well as their incentives,<sup>33</sup> to do so, which indeed validates our working assumption.

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<sup>31</sup>A formal analysis is available upon request. Welfare effects are particularly clear when the downstream firms have highly asymmetric innovation capabilities. For instance, if  $D_1$  were the only genuine innovator, and  $D_2$  only a potential imitator, the protection effect (the “bright” side) would improve the prospect for innovation – to the exclusive benefit of the firms, however: absent competition, the consumers would not benefit from innovation. Conversely, the “dark” side would dominate if instead  $D_2$  were the only genuine innovator.

<sup>32</sup>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.

<sup>33</sup>The 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  $\theta_U$  and  $\theta_D$  are unobservable and respectively controlled by the upstream and downstream firms. Suppose further that each  $\theta_i$  can take two values,  $\underline{\theta} > 0$  and  $(1 \geq)\bar{\theta} > \underline{\theta}$ , 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,  $\bar{\theta}\bar{\theta}$ ; as a result, vertical integration can indeed increase the likelihood of imitation. More precisely:

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

**Proof.** See Appendix C. ■

Finally, we now stress that vertical integration drastically alters suppliers' incentives to exploit or protect their customers: while independent suppliers have incentives to maintain a good reputation, integrated suppliers may instead entertain the fear of information leakages and imitation in order to benefit from foreclosure. To see this, we now endogenize the suppliers' reliability in protecting customers' information.

In practice, a supplier can 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. For the sake of exposition, we focus on the case where suppliers choose whether to invest in a costly reverse-engineering capability; we show in Allain, Chambolle and Rey (2011) that a mirror analysis, yielding

similar results, holds when suppliers can offer guarantees or set-up firewalls (that is, when being unreliable is costless while being reliable may be costly).

### 3.1 Reverse engineering: a simple analysis

To capture the intuition in the simplest way, we introduce here a preliminary stage in which *both* suppliers (vertically integrated or not) choose whether to invest in reverse-engineering, and modify the continuation game accordingly:

- In stage 0,  $U_A$  and  $U_B$  simultaneously decide (publicly and irreversibly) whether to invest, at cost  $F$ , in reverse-engineering.
- In stage 1,  $D_1$  and  $D_2$  simultaneously choose their R&D efforts and then innovate with probabilities  $\rho_1$  and  $\rho_2$ ; 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, suppliers who have invested in reverse-engineering 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  $\theta > 0$ .

By construction, suppliers who do not invest in reverse engineering 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  $\delta$ . By contrast, an integrated supplier will never sell internal information to its rival, since the gain  $\delta$  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), and 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.<sup>34</sup>

**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. ■

Note that even an integrated supplier would never invest in reverse engineering once downstream innovation investments have taken place; however, if suppliers can *choose* when to invest in reverse-engineering, an integrated firm will again invest (if it is not too costly) *ex ante*, before *R&D* decisions are taken, in order to benefit from the resulting foreclosure effect. By contrast, a separated firm never invests in reverse-engineering, neither *ex ante* nor *ex post*.

## 3.2 Reverse-engineering in a dynamic context

Vertical integration thus drastically affects suppliers' decisions to be reliable or not, as they benefit from foreclosure in the latter case. This insight was derived above in a static setting where suppliers could somehow credibly commit themselves to being reliable or not. We now show that the same applies when reliability decisions are no longer observable, but have lasting effects: the integrated firm can then demonstrate its imitation capability by exploiting its customers' information in early periods, and benefit from foreclosure in subsequent periods.

To see this, consider a two-period variant of the above model, where investments in reverse engineering are no longer observable, but take place after procurement choices and enable the firms to imitate in both current and future periods. Assuming that duplication, and/or its impact on the innovator's profit, is observable, a supplier who exploits its customer's information in the first period then reveals that it is in a position to do so again in the second period. We assume again  $F > \delta$ , and suppose that firms use a common discount factor  $\beta$ .

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<sup>34</sup>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.

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, which then succeed or fail 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:

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

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 E for a formal analysis):

**Proposition 10** *If (16) holds, then.*<sup>35</sup>

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

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

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

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<sup>35</sup>In the limit case  $\theta(\Delta - 2\delta) = \beta(\Pi^{VI} - \Pi^{VS}) - F$ , foreclosure may arise in either the first or both periods.

## 4 Reputation

The previous section shows that foreclosure arises even when suppliers can reveal their reliability, either directly (if it is readily observed by customers) or indirectly (through lasting effects). We now rule out any form of commitment or irreversibility, and consider instead a dynamic framework with unobservable, short-lived reliability decisions; we show that vertical integration can then distort suppliers' decisions and induce them to build a reputation of unreliability.

Thus, suppose now that suppliers must invest in reverse engineering in each period, in order to exploit their customer's information *in that period*. Suppose furthermore that, while some suppliers must spend an amount  $F > \delta$  in order to exploit a customer's information, others can do so at no cost. We will refer to the former as "good" types and to the latter as "bad" types.<sup>36</sup> 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  $\rho_1$  and  $\rho_2$ ; 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

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<sup>36</sup>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.

deciding whether to exploit its customers' information.<sup>37</sup> 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) 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.<sup>38</sup>

We show below that integration drastically affects  $U_A$ 's incentive to appear reliable:<sup>39</sup> 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 F.

## 4.1 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  $U_A$  would obtain the same revenue from winning the competition, 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  $U_B$

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<sup>37</sup>This simplifies the analysis, by ruling out signalling issues in the first price competition stage.

<sup>38</sup>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).

<sup>39</sup>We show below that a downstream firm would indeed rather integrate with the unreliable supplier.



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:

$$\Pi_i = \rho_i (1 - \rho_j) (\Delta - T_B) - C(\rho_i) = \rho_i (1 - \rho_j) p_A \Delta - C(\rho_i). \quad (18)$$

In the vertical separation case, the equilibrium R&D efforts are again symmetric but lower than  $\rho^*$ :  $\rho_1 = \rho_2 = \hat{\rho}^*(p_A) < \rho^* = \hat{\rho}^*(1)$ . 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:

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

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  $\hat{\pi}_B(p_A) \equiv \hat{\rho}^-(p_A) (1 - \hat{\rho}^+(p_A)) (1 - p_A) \Delta$  (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 11** *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  $\pi^*$  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 F.1. ■

## 4.2 First period

Consider now the first period. From proposition 11, 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,  $\pi^*$ , 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 F.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  $\check{\rho}^*(p)$ , which is positive as long as  $p > 0$ , and obtains a total expected discounted profit of the form  $\check{\pi}^*(p) + \beta\hat{\pi}^*(p)$ , where  $\check{\pi}^*(p) > 0$  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  $\pi^*$  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:

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

$U_A$  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,  $\Delta$ , and there is thus complete foreclosure. We thus have:

**Proposition 12** *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 F.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).

### 4.3 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:

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

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:

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

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  $\Delta$  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 13** *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.<sup>40</sup>

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 14** *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 F.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),<sup>41</sup> then a "bad" supplier, namely,

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<sup>40</sup>That is, the independent downstream rival has access to the same supply conditions as in the vertical separation case.

<sup>41</sup>Degrading the quality offered to rivals may for example require distinct production lines, which reduces scale economies and increases organizational costs.

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.

## 5 Conclusion

This article shows that vertical integration may generate foreclosure when firms 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 the threat of information disclosure, which reduces the benefit of investments (in R&D, production capacity, ...). For instance, foreclosure arises, even in the absence of any commitment or *ex post* contractual inefficiency, whenever vertical integration creates or exacerbates the risk that sensitive information transmitted to the integrated supplier would be exploited by its downstream subsidiary: concerns about the integrated supplier’s reliability confer market power to the other suppliers, forcing downstream rivals to share the benefits of their investments with the remaining suppliers, thereby discouraging their efforts.

We further show that vertical integration indeed drastically affects a supplier’s incentive to protect or exploit its customers’ sensitive information. Where an independent supplier has an incentive to protect its customers’ information, 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’ information (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’ information. Similar insights apply when information transmitted to the downstream division can be exploited by the integrated supplier. 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 performance, consumers, and welfare would then be more ambiguous. Also, if there is substantial market power upstream, then the downstream foreclosure benefit may be offset by the loss of market share and profit upstream. 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.<sup>42</sup> 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.<sup>43</sup> 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

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<sup>42</sup><http://money.cnn.com/1999/05/31/companies/gm/>

<sup>43</sup>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”.

own subsidiary to the downstream rival, and vertical integration may benefit consumers as well as firms.

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# 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  $P(\cdot)$  satisfies  $P'(\cdot) < 0$  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  $\rho_i$  so as to maximize  $\pi(\rho_i, \rho_j) - C(\rho_i)$ , which yields:<sup>44</sup>

$$P(\rho_1 + \rho_2) + P'(\rho_1 + \rho_2)\rho_i = C'(\rho_i). \quad (23)$$

Capacity decisions are strategic substitutes and there is a unique, stable symmetric equilibrium  $\rho_1 = \rho_2 = \rho^*$ .<sup>45</sup>

- 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  $\rho^R$  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  $\pi_2(\rho_2, \rho_1; \theta)$ .<sup>46</sup>

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<sup>44</sup>The expected profit is concave in  $\rho_i$ , since its second order derivative,  $2P'(\rho_i + \rho_j) + P''(\rho_i + \rho_j)\rho_i$ , is negative under the above assumptions.

<sup>45</sup>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.

<sup>46</sup>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:

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

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  $\rho_1$  or  $\rho_2$  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.<sup>47</sup>

## 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:

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

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  $\rho^R$ ; by continuity, this still holds when investment costs are not too large.

<sup>47</sup>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  $D_1$ :

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

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

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,  $d\rho_\theta/d\theta \leq 0$  only for  $\theta \leq \bar{\theta}(\eta) \equiv (\eta - 1)^2$ , where  $\bar{\theta}(\eta)$  is positive and increases with  $\eta$  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  $\phi$  to the supplier in case of successful imitation. The risk of imitation is then maximal (that is,  $\theta_U = \theta_D = \bar{\theta}$ ) if and only if:

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

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

$$\delta \geq \frac{2b}{(\bar{\theta} - \underline{\theta})\bar{\theta}}. \quad (24)$$

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

The latter constraint is the more demanding<sup>48</sup> and amounts to:

$$\delta \geq \frac{2b}{(\bar{\theta} - \underline{\theta})(\bar{\theta} + \underline{\theta})}, \quad (25)$$

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  $\delta$ . 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  $\Pi_i(\rho_i, \rho_j)$  and both investments are equal to  $\rho^*$ .  $U_A - D_1$ ’s expected profit is thus still equal to  $\Pi^*$ .
- 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  $F < \Pi_\theta^+ - \Pi^*$ .

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<sup>48</sup>To see this, note that they are respectively equivalent to  $b \leq \delta(\bar{\theta} - \underline{\theta})\bar{\theta}$  and  $b \leq \delta(\bar{\theta} - \underline{\theta})\frac{\bar{\theta} + \underline{\theta}}{2}$ . The conclusion then follows from  $\bar{\theta} > \underline{\theta}$ .

## E 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,<sup>49</sup> asymmetric upstream competition then leads  $U_A$  to offer a discount  $-\theta\delta$  and  $U_B$  to win with a positive tariff 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:

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

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  $\delta$  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:

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<sup>49</sup>That is, assuming that  $D_2$  does not revise its belief when receiving an out-of-equilibrium offer in period 2.

- 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  $\delta$  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:

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

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:

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

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).

## F Reputation

### F.1 Proof of Proposition 11

#### F.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:

$$\Pi_i = \rho_i (1 - \rho_j) p_A \Delta - C(\rho_i). \quad (26)$$

The resulting equilibrium R&D efforts are symmetric but lower than  $\rho^*$ :

$$\rho_1 = \rho_2 = \hat{\rho}^*(p_A) < \rho^* = \hat{\rho}^*(1). \quad (27)$$

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:

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

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

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

Therefore:

$$\hat{\pi}^{*/'}(p_A) = \frac{\hat{\rho}^*(p_A)(1 - \hat{\rho}^*(p_A)) \Delta C'''(\hat{\rho}^*(p_A))}{C''(\hat{\rho}^*(p_A)) + p_A \Delta} > 0. \quad (28)$$

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

### F.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  $\pi_B = \hat{\rho}^-(p_A)(1 - \hat{\rho}^+(p_A))(1 - p_A)\Delta$ . 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  $\rho^*$  to 0 ;
- $\hat{\rho}^+(p_A)$  therefore increases  $\rho^*$  to  $\rho^m$ , the monopoly level satisfying  $C'(\rho^m) = \Delta$ ;
- as a result,  $\hat{\pi}^+(p_A)$  increases from the competitive level  $\pi^*$  to the monopoly level,  $\pi^m = \max_{\rho} \rho \Delta - C(\rho)$ .

## F.2 Proof of Proposition 12

We consider in turn the separation and integration cases.

### F.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:

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

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

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:

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

which would give  $D_i$  an expected profit equal to:

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

This best offer beats  $U_A$ 's one, since:

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

where  $\phi(p) > 0$  for  $p < 1$ , since  $\phi(1) = 0$  and, using (28):

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

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:

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

It follows that the R&D equilibrium is symmetric:

$$\rho_1 = \rho_2 = \check{\rho}^*(p),$$

characterized by the first-order condition:

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

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

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

where the numerator is positive since:

$$\beta\hat{\pi}^{*'}(p) = \beta\hat{\rho}^*(1 - \hat{\rho}^*) \frac{C''(\hat{\rho}^*)}{C''(\hat{\rho}^*) + p\Delta} \Delta < \Delta, \quad (29)$$

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  $\check{\pi}^*(p) + \beta\hat{\pi}^*(p)$ , where:

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

### F.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  $\Delta$  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 15** *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  $\mu_b$  when it is bad, and with probability  $\mu_g$  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

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

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<sup>50</sup>  $\hat{\pi}^+(1) = \pi^*$  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 ( $\mu_g = \mu_b = 1$ ): 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:

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

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 if it turns out to be of a good type. Therefore,  $D_2$  and  $U_A - D_1$  are better off not dealing

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<sup>50</sup>If  $\mu_g < 1$ , then not imitating "reveals" a good type (i.e., the second-period belief is  $p_A^n = 1$ ). If  $\mu_g = 1$ , the second-period belief is not uniquely defined; we assume that it remains equal to  $p_A^n = 1$ .

with each other. By contrast,  $D_2$  and  $U_B$  can together generate an extra profit  $\Delta$ . 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  $\rho^m$ .

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:

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

where the last inequality stems from (using (29)):

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

and:

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

### F.3 Proof of Proposition 14

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:

$$C'(\rho_1) = (1 - \rho_2(2 - p_A))\Delta, C'(\rho_2) = (1 - \rho_1)p_A\Delta, \quad (30)$$

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 ( $\rho^*$  and  $\pi^*$ ) 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:

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

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:

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

which would give  $D_2$  expected profits equal to:

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

The latter is likely to be higher;<sup>51</sup> in particular, we have:

**Lemma 16**  $\tilde{\pi}_2^B > \tilde{\pi}_2^A$  when  $p$  is close to 1.

**Proof.** To see this, define

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

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<sup>51</sup>It can for example be shown that this is always the case when  $C''(\cdot) > 2\Delta$ . This is also the case when  $p$  is close to 0, since then  $\tilde{\pi}_2^B = \Delta > \tilde{\pi}_2^A = 0$ .

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 (30) yields:

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

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

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

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:

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

Therefore, investing firms' total expected discounted profits become:

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

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

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



These investment levels converge respectively to  $\rho^*$  when  $p$  tends to 1, and in the limit the integrated firm simply obtains  $\pi^*$  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.