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Abstract

This paper examines vertical integration incentives in the presence of a cost-reducing technology. Combining the technology adoption and vertical merger literatures in a simple duopoly model, I show that asymmetric integration can occur even in a purely symmetric set-up, without synergies or foreclosure incentives. This paper makes three further contributions. First, in this model, integration is profitable whenever it allows the firm to adopt the technology faster and to become a profitable technology leader for a longer period of time. Second, comparing preemption and precommitment game, I show that the asymmetric equilibrium may exist under both types of game. Third, vertical integration generally reduces consumers' surplus, but often competition authorities should not forbid such vertical mergers if they seek to maximize social welfare.

JEL-Code: L11, L22, L42, O33

Keywords: precommitment game, preemption game, timing of technology adoption, vertical relations, vertical integration

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1 Introduction

Understanding the motivations behind merger choices is a core concern of competition researchers and policy-makers. Such decisions have a crucial impact on the market's performance. Determining whether these serve efficiency or anticompetitive purposes is then an essential task for the Industrial Organization economist. Facing the increasing number of merger notifications,¹ the guidelines about the analysis of horizontal mergers became very precise over the years, but those about vertical mergers (henceforth integrations) are still subject to debates. The first ones relate to the merger of two competitors (i.e. operating in the same market), while the second one relates to merger of two trading partners operating at different levels of a vertical supply chain (i.e. an upstream firm and a downstream firm).

Concerning the motivations behind vertical integration decisions, the literature covered two main features: synergies and foreclosure. The first one claims that, in line with the Chicago school of thought, integration will occur only if it yields cost efficiencies. The second one claims that, in line with the seminal paper of Hart and Tirole (1990), integration may serve foreclosure strategies, which consist in merging with a downstream/upstream partner in order to prevent a competitor accessing a segment of the market. As a matter of fact, the first analysis defends a pro-competitive nature of integration (whereby all firms active in the market should integrate their partner if the synergies are industry-specific), whereas the second one defends an anti-competitive view of integration (whereby one firm willing to integrate a partner while the others don't should be viewed suspiciously).

Such analyses are focusing essentially on the impact of vertical relations on competition, and much less about the impact of such relations on market performance. There exists an extensive Industrial Organization literature on the impact of vertical relations and vertical restraints on several features of the market, such as innovation. Indeed, the vertical structure of a firm considerably affects the efficiency of the Research and Development investments (henceforth R&D) it undertakes.

Therefore, it seems essential to develop a conceptual framework such that the effect of vertical relations on competition and on market performance are both evaluated at the same time. In a world where technologies are becoming essential assets for most industries, it seems unreasonable to consider integration decisions as being independent of any R&D challenges: firms have to deal with all these considerations at the same time. This is why I study a duopoly model where vertical structures are making both integration and technology adoption decisions. Two vertical chains (i.e. an upstream firm dealing with a

¹According to the European Commission website, the number of merger notifications went from 11 in 1990 to 362 in 2016, with a peak at 402 notifications in 2007.

downstream firm exclusively) are then choosing whether to integrate or not and the time at which they will adopt a cost-reducing technology, before bargaining over contract terms (when the structure remains separated) and compete in quantities (*i.e.* *à-la* Cournot).

I make the link between the vertical integration literature and the timing of technology adoption one, and the combination of integration and innovation incentives yields three main contributions to the literature.

My first contribution concerns the effect of the technology adoption decision on the integration incentives. I study an integration game, where both firms decide whether to integrate or not depending on the profitability of the operation for the entire structure.² I show that in my model, the profitability of the integration stems purely from its impact on the timing of adoption: since the per-period profits of the structure are generally higher when separated, integration is profitable only when it allows the firm to become the technology leader and adopt the technology first. Such integration's profitability depends on the vertical structure of the competitor, and this is how I obtain an asymmetric equilibrium in which only one firm integrates. This novel result holds in a perfectly symmetric set-up, without any synergies or foreclosure incentives.

My second contribution concerns the exploration of the different technology adoption games. Building on my previous work (Voudon (2019)), I investigate the impact of the type of technology adoption game on the outcome of the merger game, and significant differences between the preemption game and the precommitment game are highlighted. In the precommitment game, integration is profitable whenever the firm knows it will be the technology leader once integrated, whereas its technology position is uncertain under a symmetric set-up. Under the preemption game, integration is profitable whenever the firm knows it will be able to adopt at the precommitment timing once integrated, whereas it would have been forced to adopt at a less profitable timing due to preemption pressure from its competitor in a symmetric context.

My third contribution concerns the welfare analysis of the integration decisions of the firms. I evaluate the impact of the integration on consumers' surplus and social welfare. In the model, consumers generally prefer separation (which yields higher output) but may prefer integration if adoption is accelerated to a significant extent. When considering the total surplus, the market reaches the optimal outcome for most parameter values.

This work relates to several literatures. A first one is dedicated to the study of vertical relations and their link with innovation. Indeed, an important branch of vertical relations is dedicated to the non-price strategies of the different agents of a market, and how the vertical structure of this one affects R&D investments. For instance, Stefanadis (1997),

²In the model, the vertical structure decides to integrate whenever the integrated profits are higher than the sum of the upstream and downstream profits when separated.

Banerjee and Lin (2003), Chen and Sappington (2010), Banerjee and Lin (2003), Faulí-Oller et al. (2011) and Milliou and Pavlou (2013) develop models in which innovation is an extra strategic parameter affected by vertical relations.

This paper relates also to the integration literature. This classical branch of Industrial Organization focused on the incentives to integrate a downstream partner, and on the impact of such decision both in competitive and innovative terms (*e.g.* Bonanno and Vickers (1988), Salinger (1988), Hart and Tirole (1990), Stefanadis (1997), Riordan (1998), Farrell and Katz (2000), Brocas (2003), Buehler and Schmutzler (2008), Beladi and Mukherjee (2012), Allain et al. (2014) and Liu (2016)). My paper is a contribution to this literature as it studies the integration incentives of a duopoly in the presence of a cost-reducing technology, in a dynamic framework. In particular, I show the existence of an asymmetric equilibrium where only one firm integrates. I obtain such result introducing the features of timing of technology adoption models in my merger game.

Bonanno and Vickers (1988) constitutes a cornerstone work on vertical integration incentives. They show that in the case of two competing vertical structures, vertical separation may be a better strategy for the upstream firms. The idea is that in a duopolistic situation, the negotiation between the retailer and the manufacturer may turn out to be an advantage for the upstream firm: assuming a two-part tariff (*i.e.* a wholesale price and a franchise fee), they show that each manufacturer is better off staying vertically separated and charging a wholesale price higher than marginal costs. In my model, I develop a similar model where two vertical structures compete, but the introduction of technology adoption will alter this result, as vertical integration exhibits benefits for the upstream firm in terms of adoption time.

Finally, the closest works to this paper are the ones of Alipranti et al. (2015) and Buehler and Schmutzler (2008). Alipranti et al. (2015) compare the timing of technology adoption under input outsourcing and input insourcing, and show that the presence of vertical relation may accelerate the adoption of new technology. I exploit most of their model's features and adapt them to a vertical merger application. My work extends their work by considering the asymmetric case where only one firm is vertically integrated, and making the merger decision endogenous. Buehler and Schmutzler (2008) study the integration incentives with the presence of a cost-reducing technology, and demonstrate the existence of an asymmetric equilibrium. My work extend their result to a dynamic framework (as they use a static model) and to other parameters of interest: I focus on bargaining power and technology efficiency, whereas they look at the market capacity and the adoption costs. In addition, I develop policy implications and welfare analysis.

Finally, this paper is the continuation of my previous work, Voudon (2019). While I investigated the impact of the vertical structure on the timing of adoption under the different

adoption games, I endogenize here the integration decision, based on the same model. In doing so, I deepen the understanding of the link between vertical structure and technology adoption: taking into account the effect of integration on the technology adoption patterns, firms make merger decisions crucially influenced by innovation concerns.

The paper proceeds as follows. In Section 2, the set-up of the model and timing of the game are presented. In Section 3, the last three stages of the game are solved. In Section 4 and 5, the merger game is solved under the precommitment game and the preemption game respectively. Finally, in section 6, policy implications are discussed.

2 The Framework

In the following section, the model is described. The set-up is identical to the one in Voudon (2019): just an additional stage is added to the game. Then, I remind the main features of the model and expose the additions of this work.

2.1 The Set-Up

I consider a market where there are two upstream firms, U_A and U_B , and two downstream firms, D_A and D_B , selling a homogeneous good. A given upstream firm i faces a marginal cost of production c_i (where $i \in \{A, B\}$), and downstream firms face no costs apart from the contracted two-part tariff. This contract consists of a wholesale price w_i and a fixed fee f_i , determined by a Nash bargaining process, where $\beta \in [0, 1]$ is the bargaining power of the upstream firm. Each upstream manufacturer deals with one downstream firm exclusively, *i.e.* U_A deals with D_A and U_B deals with D_B . Demand for final good is $P(Q) = a - Q = a - q_A - q_B$, where q_i is the quantity produced by downstream firm i . The set-up is represented in Figure 1.

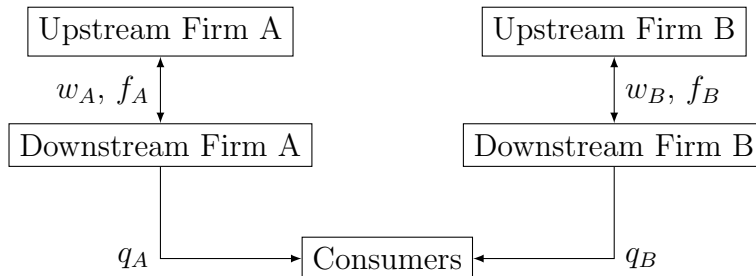


Figure 1: The Set-Up

Time t is continuous and has infinite horizon. At $t = 0$, a new cost-reducing technology is available, and when adopted, it reduces upstream marginal costs by Δ (*i.e.* marginal costs go from c to $c - \Delta$). In addition, the present value of adoption costs $k(t)$ reduces

with time. The current cost of adoption $k(t)e^{rt}$ is decreasing but at a decreasing rate, where r is the interest rate³.

I make the same two standard assumptions as in Voudon (2019), in order to ensure that both vertical structures are active (*i.e.* $q_i > 0$) and that marginal costs remain positive in all cases (*i.e.* $c - \Delta > 0$).

Assumption 1. $M \equiv a - c < \frac{a}{2}$ and $\delta \equiv \frac{\Delta}{M} < \frac{1}{2}$

where M is the market capacity (always positive) and δ captures how drastic the innovation is (always positive), relative to the market capacity.

Assumption 2. • $(k(t)e^{rt})' < 0$ and $(k(t)e^{rt})'' > 0$

- $\lim_{t \rightarrow 0} k(t) = -\lim_{t \rightarrow 0} k'(t) = +\infty$ and $\lim_{t \rightarrow \infty} k'(t)e^{rt} = 0$
- $r(\pi^l - \pi^0)e^{-rt} < k''(t)$

2.2 The Timing of the Game

The timing of the game is as follows: at Stage 1, the vertical structures, initially separated, decide non-cooperatively and sequentially whether they integrate their downstream partner or not (the merger game assumptions are further discussed in Subsection 2.3). Then, at Stage 2, each upstream firm U_i (firm i when integrated) decides simultaneously its adoption date T^i . In the precommitment game, they commit to such timing at $t = 0$. In the preemption game, they choose to adopt or not at every stage. No other technologies are made available during the rest of the game, and firms cannot change their adoption decision.⁴ Then, at each $t \geq 0$, each upstream - downstream firm pair bargains simultaneously over the contract terms (Stage 3). Finally, D_A and D_B simultaneously set their quantities (Stage 4). Figure 2 represents the timing of this game.

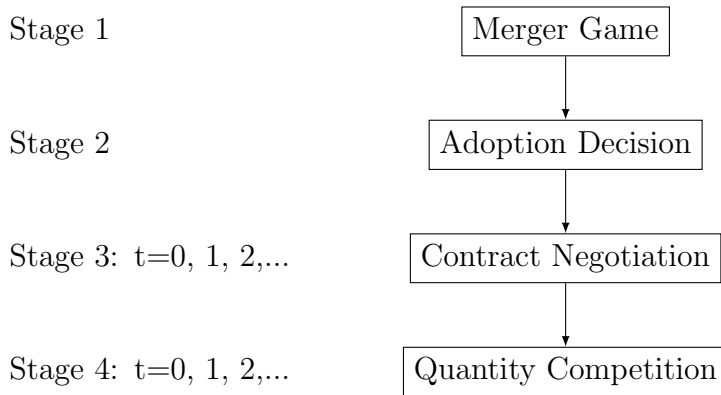


Figure 2: The Timing

³These assumptions are standard in the timing of technology adoption literature.

⁴These are the standard assumptions of the precommitment game as introduced by Reinganum (1981).

I proceed by backward induction, solving the quantity competition, the contract negotiation and the technology adoption game first for every possible type of vertical structure of the market. Voudon (2019) solved all these steps and did an extensive discussion of the precommitment and preemption timing under the different vertical set-ups. Hence, I will first remind these results, and then develop the solving of the merger game, under the precommitment game first, under the preemption game then.

2.3 The Merger Game in Extensive Form

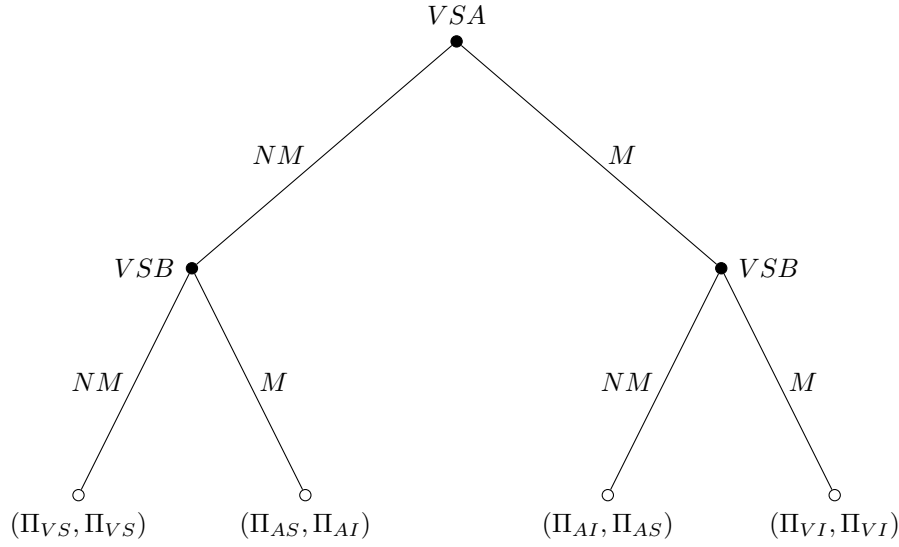


Figure 3: The Merger Game

The merger game is now further described. Let's visualize the merger game thanks to an extensive form, in Figure 3. Before choosing the timing of adoption, each firm decides on its vertical structure (*i.e.* either remaining vertically separated, or becoming vertically integrated). A firm decides to merge if the integrated profits are higher than its joint profits when separated (*i.e.* the sum of the upstream and downstream profits). For the sake of simplicity, firms are assumed to not make their merging decision in the same time: the game is sequential.⁵ *VSA* and *VSB* stand for “Vertical Structure A” and “Vertical Structure B” (assuming that, without loss of generality, A makes its decision first). *M* and *NM* stand for “merger” and “no merger”. Finally, the payoffs corresponds to the stream of profits.

As described in Figure 3, three different vertical set-ups may arise. The vertically separated case, represented in Figure 1 and denoted *VS*, is the case in which both firms are

⁵This assumption is essentially made for tractability purposes. Intuitively, if the simultaneity of the adoption games is a sensible assumption (since the technology is released in the same time for the entire industry), it seems rather implausible to do the same for the merger game: nothing would induce firms to take such decision in the same time. The assumption that firms choose whether to merge or not, knowing the others' vertical structure, seems reasonable.

separated. The vertically integrated case, represented in Figure 4 and denoted VI , is the case in which both firms are integrated.



Figure 4: The Vertically Integrated Case

The asymmetric case, represented in Figure 5, is the case in which one firm is integrated and the other one is separated. The integrated one is denoted AI (for asymmetrically integrated) and the separated one is denoted AS (for asymmetrically separated).

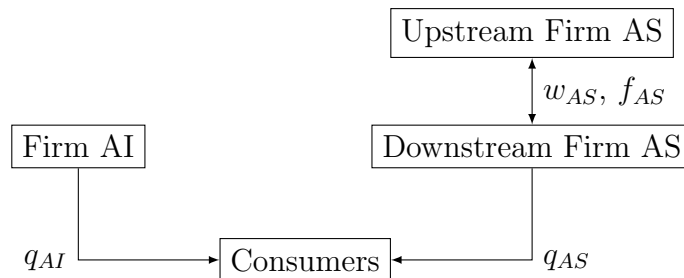


Figure 5: The Asymmetric Case

2.4 A Specific Adoption Cost Function

In order to solve the merger game, I have to compare the profitability of the different vertical set-ups. To compare these profits, a specific adoption costs function $k(t)$ has to be chosen. A classical function exploited in several papers (introduced by Fudenberg and Tirole (1985)) is $k(t) = e^{-(\alpha+r)t}$, where $\alpha > 0$ is the rate at which the current costs of adoption are falling. Taking an interest rate of 3% ($r = 0.03$), the adoption costs function is represented in Figure 6. One has to set a minimum value for α below which any of these timings could be negative.⁶

Assumption 3. When $k(t) = e^{-(r+\alpha)t}$, $\alpha \geq 0.42M^2$.

⁶In fact, this is just an extra assumption to fit Assumption 2 requirements concerning the adoption cost function.

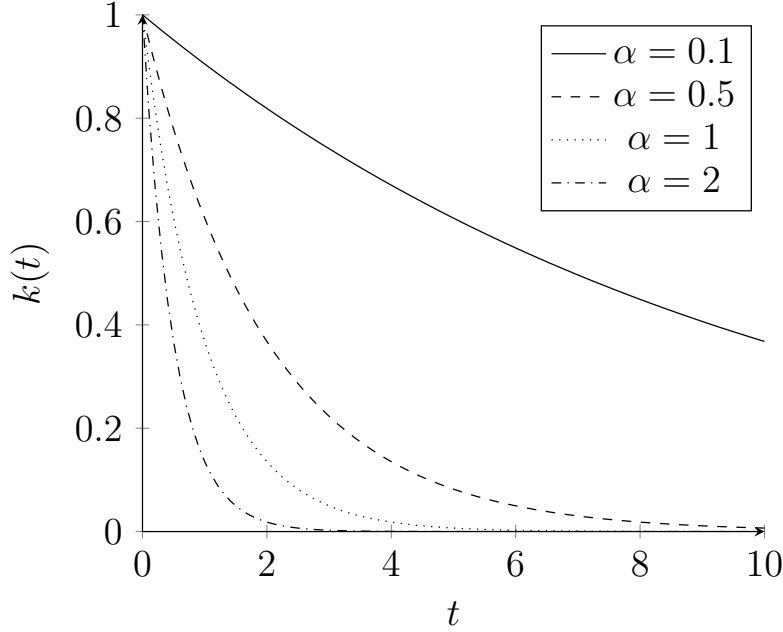


Figure 6: Adoption Costs Function $k(t) = e^{-(r+\alpha)t}$

3 Technology Adoption, Contract Negotiation and Quantity Competition

In this section, I cover the last three stages of the game. These have been extensively discussed in Voudon (2019). This is why I cover just the main features of the models and their results (summarized in Table 1).

First, I solve the quantity competition. This is a standard Cournot model, and maximizing (downstream if separated) profits with respect to quantity yields the equilibrium quantities as a function of upstream marginal costs (wholesale prices if separated).

Second, I solve the contract negotiation, when the vertical structure is separated. It consists in maximizing the Nash bargaining program (equation (1)) where β is the upstream bargaining power, with respect to the fixed fee f_i and the wholesale price w_i . Solving for the fixed fee first, the wholesale price is then set in order to maximize the joint profits (*i.e.* the sum of upstream and downstream profits), and the fixed fee is used to share these. The upstream firm gets a share β of the joint profits, whereas the downstream firm gets a share $(1 - \beta)$.

$$\max_{w_i, f_i} (\pi_i^{U-} + f_i)^\beta (\pi_i^{D-} - f_i)^{(1-\beta)} \quad (1)$$

where π_i^{U-} and π_i^{D-} are the gross profits of the upstream firm and the downstream firm respectively.

Hence, equilibrium quantities, wholesale prices and per-period profits are obtained, for each possible vertical structure: the vertically separated case, the vertically integrated case, and the asymmetric case.

Under the precommitment game, the firms (upstream if separated) maximize their infinite stream of discounted per-period profits with respect to their timing of adoption at time $t = 0$, and commit to it for the rest of the game. I call the first adopter the technology leader, and the second adopter the technology follower. Therefore, the technology leader maximizes its profits with respect to T_1 and the technology follower maximizes its profits with respect to T_2 , as in Equations 2.

$$\begin{aligned} \max_{T_1} \quad \Pi_1^i(T_1, T_2) &= \int_0^{T_1} \pi_i^0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_i^l e^{-rt} dt + \int_{T_2}^{\infty} \pi_i^b e^{-rt} dt - k(T_1) \\ \max_{T_2} \quad \Pi_2^j(T_1, T_2) &= \int_0^{T_1} \pi_j^0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_j^f e^{-rt} dt + \int_{T_2}^{\infty} \pi_j^b e^{-rt} dt - k(T_2) \end{aligned} \quad (2)$$

where $\pi_i^0 = \pi_i^*(c, c)$, $\pi_i^l = \pi_i^*(c - \Delta, c)$, $\pi_i^b = \pi_i^*(c - \Delta, c - \Delta)$ and $\pi_i^f = \pi_i^*(c, c - \Delta)$.

Firm i and j are identical in the symmetric cases, not in the asymmetric case. The superscript 0, l , f and b denote, respectively, the case where no firms have adopted the technology, the case where the firm has adopted the technology but not the competitor, the case where the firm has not adopted the technology but the competitor did, and the case where both firms have adopted the technology. The general form of the first order conditions is presented in Equation (3). Denoting:

$$\begin{aligned} I_1^i &\equiv \pi_i^l - \pi_i^0 \\ I_2^j &\equiv \pi_j^b - \pi_j^f \end{aligned}$$

First order conditions are:

$$\begin{aligned} I_1^i &= -k'(T_1^i) e^{rT_1^i} \\ I_2^j &= -k'(T_2^j) e^{rT_2^j} \end{aligned} \quad (3)$$

i and j are identical under the symmetric cases, and are therefore used to denote which symmetric case is considered (*i.e.* VS for the vertically separated case, VI the vertically integrated one). In the asymmetric case, i denotes the identity of the first adopter, whereas j denotes the identity of the second one (which can be either AI or AS). It is important to note that, as shown in Voudon (2019), the precommitment equilibria always exist in the symmetric cases, but do not exist for all parameter values in the asymmetric case.

Under the preemption game, the timing of second adoption is identical to the one of

the precommitment game.⁷ However, the timing of first adoption is different due to the fact that firms can immediately adjust their adoption decision to the competitor's actions (*i.e.* there are no information lags). Hence, it is a profitable strategy to preempt the competitor and adopt slightly before it until the stage where $\Pi^1(T_1, T_2^{pe}) = \Pi^2(T_1, T_2^{pe})$, which is when rents from being the technology leader is the same than the one from being the technology follower. This is the standard “rent-equalization” result from Fudenberg and Tirole (1985). Using the concept of subgame perfection, Voudon (2019) numerically solves the preemption game under the different vertical structures, as this type of game has no closed-form solution.

Hence, for every possible vertical structure, I have the equilibrium quantities, wholesale prices, per-period profits and precommitment first-order conditions. All these are summarized in Table 1.

Vertical Structure	Vertically Separated	Vertically Integrated	Asymmetric Case
Quantities	$q_i^{VS} = \frac{2}{5}(a - 3c_i + 2c_j)$	$q_i^{VI} = \frac{a - 2c_i + c_j}{3}$	$q_{AI} = \frac{a - 3c_{AI} + 2c_{AS}}{4}$ $q_{AS} = \frac{a + c_{AI} - 2c_{AS}}{2}$
Wholesale Price	$w_i^{VS} = \frac{-a + 8c_i - 2c_j}{5}$	$\times$	$w_{AS} = \frac{-a - c_{AI} + 6c_{AS}}{4}$
Per-period Profits	$\pi_i^{U^{VS}} = \frac{2\beta}{25}(a - 3c_i + 2c_j)^2$	$\pi_i^{VI} = \frac{1}{9}(a - 2c_i + c_j)^2$	$\pi_{AS}^U = \frac{\beta}{8}(a + c_{AI} - 2c_{AS})^2$ $\pi_{AI} = \frac{1}{16}(a - 3c_{AI} + 2c_{AS})^2$
First-Order Conditions	$I_1^{VS} = \frac{6}{25}\beta M^2\delta(2 + 3\delta)$ $I_2^{VS} = \frac{6}{25}\beta M^2\delta(2 - \delta)$	$I_1^{VI} = \frac{4}{9}M^2\delta(1 + \delta)$ $I_2^{VI} = \frac{4}{9}M^2$	$I_1^{AI} = \frac{3}{16}M^2\delta(2 + 3\delta)$ $I_2^{AS} = \frac{1}{2}\beta M^2\delta$ $I_1^{AS} = \frac{1}{2}\beta M^2\delta(1 + \delta)$ $I_2^{AI} = \frac{3}{16}M^2\delta(2 - \delta)$

Table 1: Summary - Equilibrium values

4 Merger decision under Precommitment game

In this section, the merger game under the precommitment game is discussed. First, the issue of equilibrium selection is investigated, and finally, the merger game is solved.

⁷This is a standard result from the preemption game literature.

4.1 Equilibrium Selection

I discuss now the issue of equilibrium selection. The problem is the following one: as one can see in Figure 3, solving the game involves computing the profitability of the integration when the competitor is separated and the one when the competitor is integrated. In particular, for the first one, I have to determine whether $\Pi_{AI} > \Pi_{VS}$, and for the second one, whether $\Pi_{VI} > \Pi_{AS}$. A firm will merge if the integrated profits are higher than the total profits of the non-integrated vertical structure (hence, $\Pi_{VS} \equiv \Pi_{VS}^U + \Pi_{VS}^D$ and $\Pi_{AS} \equiv \Pi_{AS}^U + \Pi_{AS}^D$ in Figure 3.).

Such comparison can be solved only if I have a single pay-off for each situation. However, in pure strategy, I have for every set-up two possibilities: either the firm is the technology leader, or it is the technology follower. In other words, I have two pure strategy Nash equilibria for every set-up. Then, I face an equilibrium selection issue.

The Pareto-dominance and the Risk-dominance criteria, as introduced by Harsanyi and Selten (1988), do not allow me to select one of the equilibria (*i.e.* one equilibrium does not Pareto dominate or risk dominate the other one). This is due to the fact that, in the symmetric cases (VS and VI), the two pure strategy equilibria are perfectly symmetric (Table 2 helps visualizing the “mirroring” aspect of the game).

As a result, two options are possible: either I assume full anticipation of the agents and compare all the possible pure strategies, or I assume that the firms will adopt the mixed strategy equilibrium and compare their expected profits. I explore the first option in Appendix A.1, and this approach yields trivial results: the profitability of integration results from which pay-off the firm fully anticipates. In other words, results are in a trivial sense implied by the assumptions. I therefore consider the mixed strategy equilibrium, yielding then a single pay-off for every set-up. Indeed, using the mixed strategy equilibrium is a selection criterion critically evaluated by Harsanyi and Selten (1988), and recent works, like Piccolo and Pignataro (2018), have used this option.

In the framework of the precommitment game, a mixed strategy consists in allocating a probability to each timing in order to make the other player indifferent between any timing. However, the problem is simplified observing that any other timing than T_1 and T_2 are strictly dominated strategies: whenever the competitor adopt first (second), the firm’s preferred strategy is always T_2 (T_1), whatever the other’s timing is. Hence, firms randomize only between T_1 and T_2 , and the game can be represented in a simple normal form.

In Table 2, Π_i^1 are profits of firm i when it is the leader, Π_i^2 are profits of firm i when it is the follower, Π_i^{11} are profits of firm i when both firms have adopted at T_1 and Π_i^{22} are profits of firm i when both firms have adopted at T_2 . The superscript U or D is added to

		Firm A	
		T_1^A	T_2^A
Firm B	T_1^B	(Π_B^{11}, Π_A^{11})	(Π_B^1, Π_A^2)
	T_2^B	(Π_B^2, Π_A^1)	(Π_B^{22}, Π_A^{22})

Table 2: The Precommitment Game: Normal Form.

indicate whether the pay-off are those of the upstream or the downstream firm: absent of such extra subscript, the notation indicates joint profits (*i.e.* upstream plus downstream). In the symmetric cases (VS and VI), A and B can be replaced by VS , or VI . In the asymmetric case, A is either equal to AS or to AI , and B is equal to the opposite one than A . Finally, in the VS and AS case, superscript U has to be added in Table 2 and equation (4).

Solving for p_A and p_B , respectively the probability of playing T_1^A and T_1^B :

$$p_A = \frac{\Pi_B^1 - \Pi_B^{22}}{\Pi_B^1 - \Pi_B^{22} + \Pi_B^2 - \Pi_B^{11}} \quad p_B = \frac{\Pi_A^1 - \Pi_A^{22}}{\Pi_A^1 - \Pi_A^{22} + \Pi_A^2 - \Pi_A^{11}} \quad (4)$$

In the symmetric cases, these probabilities are equal. I can now allocate a given probability to each situation (*i.e.* each entry of Table 2) and then compute expected joint profits associated with each set-up.⁸ Therefore, assuming firms are risk-neutral, expected pay-offs will take the form:

$$\begin{aligned} \Pi_A &= p_A p_B \Pi_A^{11} + p_A (1 - p_B) \Pi_A^1 + (1 - p_A) p_B \Pi_A^2 + (1 - p_A) (1 - p_B) \Pi_A^{22} \\ \Pi_B &= p_A p_B \Pi_B^{11} + p_A (1 - p_B) \Pi_B^2 + (1 - p_A) p_B \Pi_B^1 + (1 - p_A) (1 - p_B) \Pi_B^{22} \end{aligned} \quad (5)$$

In the symmetric cases, these pay-offs are equal. In fact, these expected pay-offs are easy to obtain in the symmetric case, since the equilibria exist for all parameter values, and the timings are equal. In the asymmetric case, the situation is more complicated: depending on parameter values, one equilibrium may not exist, and timings and pay-offs can be unequal. The equilibrium selection in the asymmetric case is then further discussed in Appendix A.2. A single expected profit is then obtained for every situation, allowing now their comparison.

4.2 Merger Game Solving

Now, one can study the impact of the different parameters on the profitability of first and second integration. This involves solving the equations $\Pi_{AI} - \Pi_{VS} \geq 0$ and $\Pi_{AS} - \Pi_{VI} \geq 0$

⁸The reader should note that in the separated case, upstream profits are included in the probabilities (equation (4)), but joint profits are then plugged in equation (5).

with respect to β and δ , taking M , r and α as given.

However, such equations do not have an analytical solution, due to their complicated functional form. Therefore, the game is solved numerically. In the following, I parametrize $M = 1$, $r = 0.03$ and $\alpha = 0.42$.⁹ In Appendix A.3, I explore other parameterizations and show that they do not affect qualitatively my results.

4.2.1 Profitability of Integration when the Competitor is Separated

Let's compute first $\Pi_{AI} - \Pi_{VS}$. In Figure 7, the striped area corresponds to the parameter values for which the difference between the profits when the firm is vertically integrated and the profits when it is separated is positive, with the competitor being separated.

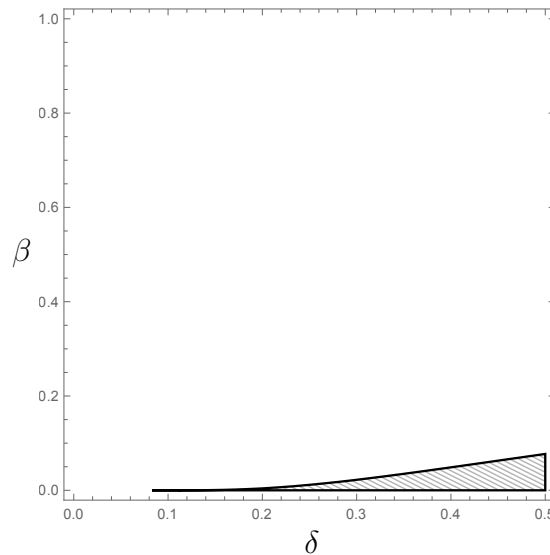


Figure 7: $\Pi_{AI} - \Pi_{VS} > 0$

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.42$. For the values of β and δ inside the striped area, integration is profitable (when the competitor is separated).

From Figure 7, one can see that under this parametrization, integration will happen only for low upstream bargaining power and high effectiveness of the technology. For these values, the vertical structure knows it will be the technology leader once integrated.

The difference between these two streams of profits may come from two main sources: the difference in terms of per-period profits and the difference in terms of timing of adoption. Let's discuss these two features.

The first feature stems from the comparison of joint per-period profits of the vertically separated firm (equations (6)) and firm AI in the asymmetric case (equations (7)), which

⁹The first parameter value is chosen for convenience, the second one is set arbitrarily to a reasonable value (a discount factor of 3%) and the third one is set to its minimum value according to assumption 3.

are expressed below. The superscripts 0, l , f and b denote the firm's profits when no firms have adopted the technology, when the firm adopted and not the competitor, when the competitor adopted the technology and the firm didn't, and when both have adopted, respectively. The subscript denotes the vertical set-up.

$$\begin{aligned}\pi_{VS}^0 &= \frac{2}{25}M^2 \\ \pi_{VS}^l &= \frac{2}{25}M^2(1+3\delta)^2 \\ \pi_{VS}^f &= \frac{2}{25}M^2(1-2\delta)^2 \\ \pi_{VS}^b &= \frac{2}{25}M^2(1+\delta)^2\end{aligned}\tag{6}$$

$$\begin{aligned}\pi_{AI}^0 &= \frac{1}{16}M^2 \\ \pi_{AI}^l &= \frac{1}{16}M^2(1+3\delta)^2 \\ \pi_{AI}^f &= \frac{1}{16}M^2(1-2\delta)^2 \\ \pi_{AI}^b &= \frac{1}{16}M^2(1+\delta)^2\end{aligned}\tag{7}$$

The integration has two effects in terms of joint per-period profits.

First, assuming for now that the timing of adoption is identical in the two cases, one can see that the per-period profits are always higher in the separated case than in the asymmetric case. This is the classical result of Bonanno and Vickers (1988): when separated, the upstream firm undertakes below-cost wholesale pricing, maximizing then the joint profits. This is indeed the *strategic* effect described by Voudon (2019): vertical separation allows the firm to enjoy a competitive advantage over its competitor.

On the other hand, under vertical separation, there is some uncertainty on which equilibrium is likely to prevail: the vertical structure may be either the technology leader or the technology follower. The market could even end up in the suboptimal situation of simultaneous adoption at time T_1 or T_2 . However, when upstream bargaining power is low, the firm will be the technology leader for sure once integrated,¹⁰ and obtain π_{AI}^l . Therefore, the per-period profitability of integration stems purely from the possibility to become a profitable technology leader once integrated, whereas this outcome is uncertain when separated.

The second feature comes from the timing of adoption. The comparison of the timings of adoption under these cases and the sources of their difference have been discussed in Voudon (2019). The impact of the timing of adoption in terms of profits can be divided in two parts: one associated to the costs of adoption and one associated to the per-period comparison of the streams of profits.

The former is related to the adoption costs difference between the two market situations due to different timing. After integration, the firm may face higher adoption costs due to earlier adoption than when it was separated. Therefore, the comparison of the cost of adoption under vertical separation and the cost of adoption under vertical integration may

¹⁰This is a result from Voudon (2019).

considerably affect the profitability of the merger. For most parameter values, integration increases adoption costs (since adoptions happen earlier in the asymmetric case).

The latter effect is related to the fact that timing of adoption affects the length of the period for which the firm enjoys a competitive advantage: once integrated, the timings of adoption may change so that the integrated firm enjoys its competitive advantage for a large period. This effect holds only for the equilibrium where the integrated firm leads: unless δ is extremely small,¹¹ $\pi_{AI}^l > \pi_{VS}^0$ and $\pi_{AI}^l > \pi_{VS}^b$. Consequently, the larger is the time span between T_1^{AI} and T_2^{AS} compared to the one between T_1^{VS} and T_2^{VS} (that is the larger is the period where the integrated firm earns its competitive advantage), the more profitable is the integration. Indeed, from the first order conditions described in Table 1, one can show that for low upstream bargaining power, the time span is bigger when the firm is integrated and the competitor is separated, compared to when both are separated.

In sum, vertical separation may be preferable considering only the *strategic* effect and the impact of integration on the adoption costs, but for the parameter values delimited by the stripped area in Figure 7, the possibility to become a profitable technology leader for a longer period of time makes integration profitable.

4.2.2 Profitability of Integration when the Competitor is Integrated

I determine now the conditions under which the second firm will prefer to merge, knowing that the other firm has merged. For the ease of graphical exposition, the incentives to remain in the asymmetric case (*i.e.* vertically separated) are henceforth studied. To do so, the joint profits of firm *AS* in the asymmetric case have to be compared to the profits in the vertically integrated case. Similarly as before, I develop some graphical solving, where the stripped area in Figure 8 depicts the parameter values for which $\Pi_{AS} - \Pi_{VI}$ is positive.

From Figure 8, one can see that under this parametrization, integration will happen only for low upstream bargaining power and high effectiveness of the technology. For these values, the firm is the technology follower when separated in the asymmetric case. Similarly as before, the difference between these two profits may come from two main features: the difference in terms of per-period profits and the difference in terms of timing of adoption.

The first feature relates to the comparison of the joint per-period profits of firm *AS* in the asymmetric case (equations (8)) and the vertically integrated firm (equations (9)). The superscripts and subscripts have the same meaning than before. Assuming for now

¹¹ $\delta < \frac{-5+4\sqrt{2}}{15} \approx 0.04$ and $\delta < \frac{-43+40\sqrt{2}}{193} \approx 0.07$ respectively.

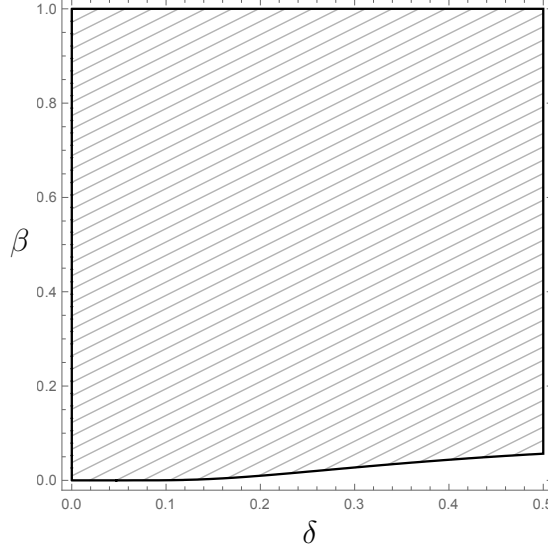


Figure 8: $\Pi_{AS} - \Pi_{VI} > 0$

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.42$. For the values of β and δ inside the striped area, integration is not profitable (when the competitor is integrated).

that the timing of adoption is identical in the two cases, one can see that the joint per-period profits of the vertically separated firm in the asymmetric case are always higher than those in the vertically integrated case. First, from a static perspective, the vertical structure is earning more profits due to optimal wholesale pricing: this is the *strategic* effect. Also, when β is low, the firm knows that it will be the technology follower if it remains separated. Especially when δ is high, integration may allow the firm to avoid the serious competitive disadvantage of being the technology follower.

$$\begin{aligned}
 \pi_{AS}^0 &= \frac{1}{8}M^2 \\
 \pi_{AS}^l &= \frac{1}{8}M^2(1 + 2\delta)^2 \\
 \pi_{AS}^f &= \frac{1}{8}M^2(1 - \delta)^2 \\
 \pi_{AS}^b &= \frac{1}{8}M^2(1 + \delta)^2
 \end{aligned}
 \tag{8}$$

$$\begin{aligned}
 \pi_{VI}^0 &= \frac{1}{9}M^2 \\
 \pi_{VI}^l &= \frac{1}{9}M^2(1 + 2\delta)^2 \\
 \pi_{VI}^f &= \frac{1}{9}M^2(1 - \delta)^2 \\
 \pi_{VI}^b &= \frac{1}{9}M^2(1 + \delta)^2
 \end{aligned}
 \tag{9}$$

The second feature relates to the timing of adoption, through two effects. A first effect is related to the adoption costs: these are generally higher for the integrated case, as adoptions occur earlier for most parameter values under this set-up. A second effect of the timing of adoption is to enlarge the period during which the vertically separated firm experiences a competitive disadvantage (when it is the technology follower). In particular, unless δ is extremely small,¹² $\pi_{AS}^f < \pi_{VI}^0$ and $\pi_{AS}^f < \pi_{VI}^b$. Therefore, the larger the time span between adoption in the asymmetric case, the more severe the competitive

¹² $\delta < 1 - \frac{2\sqrt{2}}{3} \approx 0.06$ and $\delta < \frac{3-2\sqrt{2}}{3+2\sqrt{2}} \approx 0.03$, respectively

disadvantage of being separated.

In sum, the incentives to integrate when the competitor is integrated are similar to those to integrate when it is separated. If vertical separation seems preferable from a *strategic* effect and adoption costs point of view, integration is worthwhile due to the technology follower disadvantage (when staying separated) and its impact of the time span between adoptions, for the parameter values outside the stripped area.

Hence, this model suggest there may exist incentives to prefer vertical integration to vertical separation, contrary to what Bonanno and Vickers (1988) showed. However, my result is actually confirming their intuition: Bonanno and Vickers (1988) assume that the franchise fee allows the extraction of the entire retailer surplus. In my model, it corresponds to the case where $\beta = 1$. For this parameter value, it is actually true that vertical separation is always preferable. In my model, the incentives to integrate comes from the impact of the vertical structure on the possibility and the profitability of the technology leader position. Integration is then profitable for low upstream bargaining power and high technology effectiveness values.

4.2.3 The Game's Equilibria

Let's solve the game backwards using Figure 3. The second player faces one of two situations: either the first player didn't merge (left node) or it did merge (second node). Therefore, the decision of second vertical structure to merge depends on $\Pi_{AI} - \Pi_{VS}$ when on the left node, and this decision depends on $\Pi_{AS} - \Pi_{VI}$ when on the right node. Let's denote the first player's decision according to the sign of these equations. These sign conditions correspond exactly to the areas previously presented in Figure 7 and Figure 8: hence, for graphical exposition, I superpose these two graphs in Figure 9.

If $\Pi_{AI} - \Pi_{VS} > 0$ and $\Pi_{AS} - \Pi_{VI} < 0$ (*i.e.* the vertical stripes that are not overlapping the horizontal ones), the second firm always merges, and the first firm's decision to merge depends upon $\Pi_{AS} - \Pi_{VI}$, which is negative by definition. Thus, in this situation, both firms merge and the vertically integrated outcome is the subgame unique perfect equilibrium.

If $\Pi_{AI} - \Pi_{VS} < 0$ and $\Pi_{AS} - \Pi_{VI} > 0$ (*i.e.* the horizontal stripes that are not overlapping the vertical ones), the second firm never merges, and the firm's decision depends upon $\Pi_{AI} - \Pi_{VS}$, which is negative by definition. Thus, in this situation, no firms merge and the unique subgame perfect equilibrium is the vertically separated outcome.

If $\Pi_{AI} - \Pi_{VS} < 0$ and $\Pi_{AS} - \Pi_{VI} < 0$ (*i.e.* the blank area uncovered by any stripes), the second firm merges when the first one did, and doesn't when the first one didn't. The merger choice of the first firm then depends on the comparison of Π_{VS} and Π_{VI} .

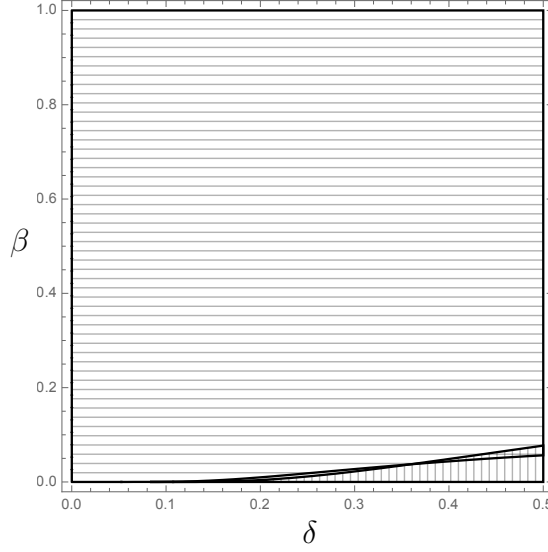


Figure 9: $\Pi_{AI} - \Pi_{VS} > 0$ and $\Pi_{AS} - \Pi_{VI} > 0$

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.42$. For the values of β and δ inside the vertically striped area, integration is profitable (when the competitor is separated). For the values of β and δ inside the horizontally striped area, integration is not profitable (when the competitor is integrated). The reader should note that there is an area covered by the two types of stripes, and another one uncovered by any of them.

Either vertical separation or vertical integration is the unique subgame perfect equilibria here, depending on the parameter values. In fact, looking back at the per-period profits equations of the vertically separated case (6) and those of the vertically integrated case (9), the vertically integrated case seem to be more profitable for both firms. Hence, if firms cooperatively chose their vertical structure, they would prefer the vertically integrated situation, but in a non-cooperative set-up, deviation (*i.e.* getting separated) is profitable. For this parametrization, the vertically integrated case is always preferable (compared the the vertically separated case), so that it is the unique perfect equilibrium for this area of the graph.

If $\Pi_{AI} - \Pi_{VS} > 0$ and $\Pi_{AS} - \Pi_{VI} > 0$ (*i.e.* the vertically and horizontally striped area), the second firm merges when the first one didn't, and doesn't when the first one did. The merger choice of the first firm then depends on the comparison of Π_{AI} and Π_{AS} . The asymmetric case is then the unique subgame perfect equilibrium here. In fact, looking back at the per-period profits of firm *AI* (7) and those of firm *AS* (8), it seems clear that a firm would still prefer to be vertically separated, even if they are being the technology follower. For this parametrization, firm *AS*'s profits are higher: thus, the first player won't merge and the second will.

Finally, it is possible to represent the game's equilibria, in terms of number of integrations, in Figure 10. For parameter values in the area 0, no integration occurs. For parameter values in the area 2, both firms integrate. In the area 1, only one integration occurs.

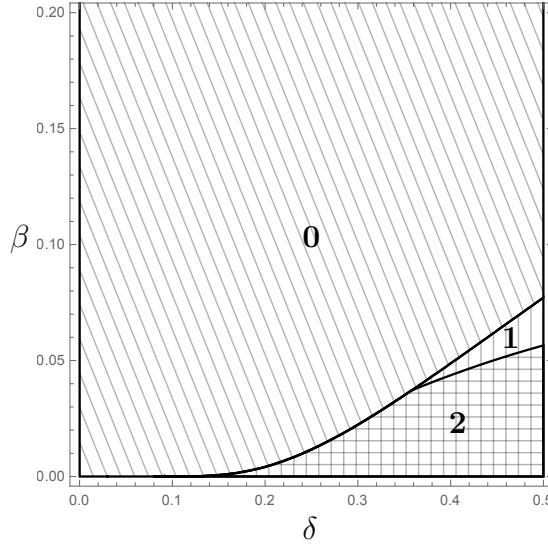


Figure 10: Number of Integrations under the Current Parametrization

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.42$. This graph is restricted to values of β below 0.2 for readability, as the rest of graph (from 0.2 to 1) is unambiguously covered by the 0 area. For the values of β and δ inside the 0 area, no integration occurs and both firms remain separated. For the values of β and δ inside the 2 area, both firms integrate. For the values of β and δ inside the 1 area, one firm integrates and the other one does not.

Finally, one can state the following proposition.

Proposition 1. *When the adoption cost is slowly decreasing with time and firms are patient, no integration occurs unless the upstream bargaining power β is very low and the effectiveness of the new technology δ is high, in which case both firms integrate. Only one integration occurs when the effectiveness of the new technology is sufficiently high and for intermediately low values of β .*

Consequently, for this parametrization, the asymmetric case occurs for a very limited range of parameter values, where β must be very low (for the integration when the competitor is separated to be worthwhile) but not too low (for the integration when the competitor is integrated to not be worthwhile), and δ must be very high. The existence of this asymmetric equilibrium stems from the fact that the incentives to integrate are slightly different when the competitor is integrated compared to when it is separated: as seen in the previous sections, it comes from the fact that the impact of integration on the timing of adoption and on the profitability of the technology leader position differs (in size) between these two situations.

The interest of this finding is to show that, starting from a purely symmetric situation, the presence of a new cost-reducing technology can allow an asymmetric equilibrium to arise. Therefore, contrary to the usual belief of competition authorities about such market situation, the fact that a firm is integrated and not the other one may not be due to anticompetitive purposes and foreclosure incentives, but simply to innovation and

technology adoption processes.

This finding is consistent with the one of Buehler and Schmutzler (2008), who also found an asymmetric integration equilibrium starting from a symmetric set-up. I extended their results to a dynamic framework: while they studied the effect of integration on the level of R&D investments, I focused on the timing of technology adoption. Also, while they express the equilibria existence conditions depending on market capacity and the cost of the technology, I focused on parameters of interest that are particularly competition relevant: the bargaining power of vertical partners, and the efficiency of a technology are metrics easily exploitable by competition authorities. In sum, our works demonstrate a consistent theory using different models.

Finally, the previous results hold for certain parameters value, that are $M = 1$, $\alpha = 0.42$ and $r = 0.03$. In Appendix A.3, I show that the parametrization does not have a qualitative impact on my results, by making reproductions of Figure 10 with higher α , lower M and higher r respectively.

5 Merger decision under Preemption Game

Now, I explore the outcome of the merger game when firms compete in technology adoption through a preemption game. First formally introduced by Fudenberg and Tirole (1985), it assumes that information lags are zero: firms know immediately about the adoption choice of the other. As a result, due to the preemption incentive, rent-equalization occurs: firms preempt each other until reaching the point where being the technology leader yields the same profits than being the technology follower. Exploring the preemption game will allow investigating further the role of the first-mover advantage on the integration decision and the existence of the asymmetric integration equilibrium. Also, the rent-equalization property of the preemption game is worth being investigated as it could solve the equilibrium selection issue: in the preemption game, the firms' pay-offs are unaffected by the technology position.

However, the solving of the preemption game involves new difficulties. The first one is that the equation giving the timing of the first adoption does not have a closed-form solution, and the profit comparison equation do not have an analytical solution either (as seen before). To solve this problem, I developed a numerical approach, in which, for a given parametrization, I compute all timings and profit values for many values of β (1000 values between 0 and 1) and δ (1000 values between 0 and 0.5).¹³ For each of these million points, I can then compute and compare the profit values and plot the range of parameter

¹³For each value of β and δ , I use a root-finding algorithm (bisection method) to find the timing of first adoption, and then I compute numerically the value of each profit stream.

values for which integration is profitable. I use the same parametrization than Voudon (2019) ($M = 1$, $r = 0.03$ and $\alpha = 0.8$) in order to be able to match my previous findings to the current. However, I run alternative parameterizations in Appendix A.3, showing that the following results are robust.

The second difficulty comes from the asymmetric case. While the solution and outcome of the preemption game under a symmetric set-up has been solved and explored many times in the technology adoption literature, the preemption game under an asymmetric set-up has never been investigated before Voudon (2019), to my knowledge. My previous work developed the solving of such game and showed which firm adopts at which position and what time. For every pair $\beta - \delta$, there is a unique subgame perfect equilibrium, hence the issue of equilibrium selection is solved in that case. In the vertically integrated case, the equilibrium selection issue is solved as well. The payoffs of the technology leader are identical to the ones of the technology follower due to the preemption incentive.

The last and main difficulty is related to the vertically separated case. The issue is due to the fact that the technology adopter is the upstream firm: the preemption game occurs with regards to the upstream profits only. Hence, rent-equalization occurs, but only at the upstream level. Therefore, when comparing the profits of the entire vertical structure (*i.e.* upstream plus downstream), it differs considerably when adopting first and adopting second, especially when β is low (*i.e.* $\Pi_{VS}(T_1^{VS_{pe}}) > \Pi_{VS}(T_2^{VS_{pe}})$). The problem is particularly serious because not only I face again an issue of equilibrium selection, but also mixed strategy equilibria cannot be used in a subgame perfection set-up. Due to the very specific nature of the preemption game, which is a sequential game where the time between actions tends to zero, there is not way to predict which equilibrium may happen.¹⁴

In this work, I have not found a way to select one of these equilibria. Keeping in mind this unsolved difficulty, I am going to solve the merger game twice: once using the payoff $\Pi_{VS}(T_2^{VS_{pe}})$ as the vertically separated profits, and once using the payoff $\Pi_{VS}(T_1^{VS_{pe}})$. I call the first option the Hypothesis 1 and the second option the Hypothesis 2. Even though it is not possible for the firm to predict which payoff it will benefit from, I will be able to solve the game conditional on whether the symmetrically vertically separated firm is the technology leader or not. If this approach is unsatisfactory from the merger game solving perspective, it allows me to develop further intuitions and mechanisms concerning the merging incentives under technology adoption.

¹⁴I have also considered the usage of the Perfect Bayesian Equilibrium concept, but since it is not possible to know who plays first in the preemption game, it is not possible to specify priors.

5.1 Merger game under Hypothesis 1

In this section, I assume that the firm will experience $\Pi_{VS}(T_2^{VS_{pe}})$ if it remains separated when the competitor is separated as well. The reasoning for the solving of the game is identical to section 4: the merger game is sequential, and a specific equilibrium may arise depending on the comparison of Π_{VS} versus Π_{AI} and Π_{VI} versus Π_{AS} . The observations previously made still hold: $\Pi_{VS} < \Pi_{VI}$ for all parameters. The following results holds for $M = 1$, $r = 0.03$ and $\alpha = 0.8$, but are robust to parametrization changes, as shown in Appendix A.3. Hence, I directly draw the merger equilibria graph, Figure 11.

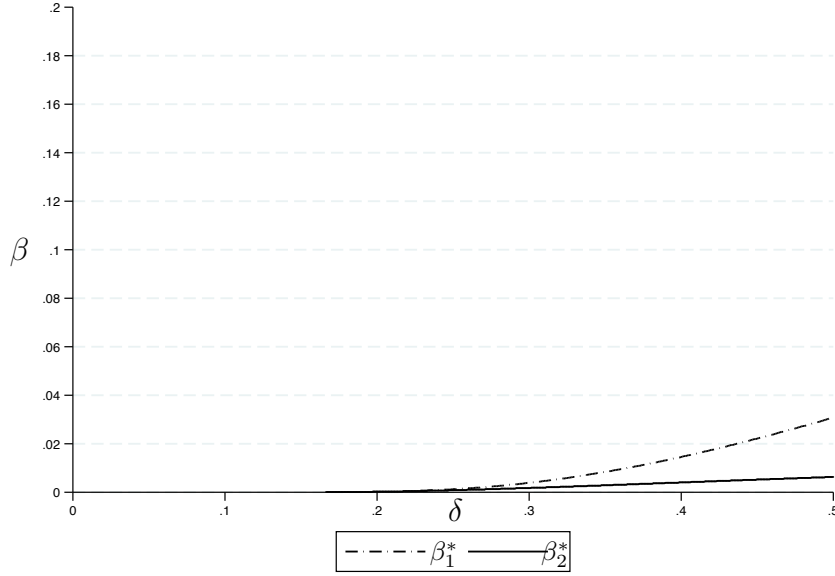


Figure 11: Number of integrations under preemption - Hypothesis 1

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. For readability, values above $\beta = 0.2$ are not represented, as they are not informative. The two thresholds delimit the three types of equilibria. Above β_1^* , both firms choose to remain separated. Below β_2^* , both firms choose to integrate. Between β_1^* and β_2^* , the asymmetric set-up occurs at the equilibrium.

Under the assumption that the firm will experience the follower's profits when separated, Proposition 1 holds. Even under the preemption game, the three equilibria may occur: one in which both firms remain separated, one in which both firms integrate, and one in which asymmetric integration occurs. The mechanism behind this result is different than under the precommitment game. Here, preemption systematically occurs under the symmetric set-ups, whereas it may not happen under the asymmetric. As shown in Voudon (2019), for low values of upstream bargaining power, in the asymmetric case, the preemption incentive of the separated firm is so low that the integrated firm can afford to adopt at the precommitment timing without any fear of being preempted. Therefore, once integrated, the integrated firm can enjoy its first-mover advantage, whereas it would have experienced lower profits due to preemption if it remained separated. On the other hand, the profits of the separated firm in the asymmetric case, even in the scenario in

which precommitment occur, are higher than the symmetrically integrated ones for most parameter values. Unless the upstream bargaining power is very low, the second firm will choose to remain separated.

In sum, when the adoption game is the preemption one, the asymmetric equilibrium arises because preemption, which systematically happen in symmetric cases and drives down payoffs, does not happen in the asymmetric set-up for low upstream bargaining power. Even if the first-mover advantage drives also the incentives to integrate, the preemption mechanism plays a crucial role in the merger game outcome, which could not be observed in the precommitment game.

5.2 Merger game under Hypothesis 2

In this section, I will assume that the firm will experience $\Pi_{VS}(T_1^{VS_{pe}})$ if it remains separated when the competitor is separated as well. This is a more conservative hypothesis as it makes the asymmetric case less likely to happen. The reasoning for the solving of the game is identical to section 4: the merger game is sequential, and a specific equilibrium may arise depending on the comparison of Π_{VS} versus Π_{AI} and Π_{VI} versus Π_{AS} . The observations previously made still hold: $\Pi_{VS} < \Pi_{VI}$ for all parameters. The following results holds for $M = 1$, $r = 0.03$ and $\alpha = 0.8$, but are robust to parametrization changes, as shown in Appendix A.3. Hence, I directly draw the final group graph, Figure 12.

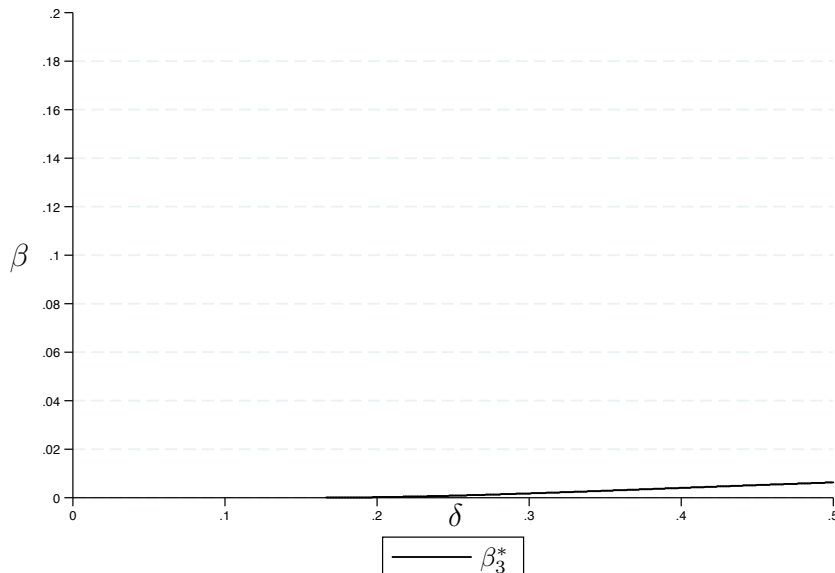


Figure 12: Number of integrations under preemption - Conservative hypothesis

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. For readability, values above $\beta = 0.2$ are not represented, as they are not informative. The threshold delimits the two types of equilibria. Above β_3^* , both firms choose to remain separated. Below β_3^* , both firms choose to integrate.

Under the assumption that firm will experience the leader's profits if it remains separated in the separated case, the merger game outcome changes. The asymmetric integration does not occur anymore, while the range of parameters for which the vertically integrated case occurs does not change. This result stems from the difference in incentives to adopt between the upstream firm and the entire vertical structure in the vertically separated case. Indeed, the upstream firm perceives only a share β of the total profits. The lower β , the later it will be able to preempt. Hence, when β is low, the upstream firm chooses a $T_1^{VS_{pe}}$ much later than the one that the vertical structure would have chosen. Hence, at $T_1^{VS_{pe}}$, especially for low upstream bargaining power, the vertical structure benefits from a large first mover advantage.¹⁵ This first mover advantage cancels out the advantage of being integrated and adopting at the precommitment timing under the asymmetric case.

Therefore, the outcome of the merger game, and the existence of the asymmetric equilibrium, crucially depends on the equilibrium selection, which cannot be solved in the preemption game. Still, such investigation showed that the existence of the asymmetric equilibrium does not rely on the type of game, and may occur because of slightly different mechanisms. I explore now the policy implications.

6 Policy implication: Merger Regulation

The role of competition authorities is to prevent practices, and in particular mergers, that would harm consumers' surplus. Hence, in this subsection, consumers' surplus must be defined. Under the assumptions of the model (*i.e.* linear demand form in quantities), the per-period consumers' surplus is simply the squared total output divided by two, $Q^2/2$.¹⁶

Hence, the infinite stream of discounted per-period consumers' surplus is:

$$cs_i = \int_0^{T_1^i} \frac{(q_i^0 + q_j^0)^2}{2} e^{-rt} dt + \int_{T_1^i}^{T_2^j} \frac{(q_i^l + q_j^f)^2}{2} e^{-rt} dt + \int_{T_2^j}^{\infty} \frac{(q_i^b + q_j^b)^2}{2} e^{-rt} dt$$

where i is the identity of the technology leader, j the one of the follower, and where the superscript has the same meaning as before. Both i and j can be replaced by VS or VI in the vertically separated and integrated cases, as the identity of the firm does not matter in the symmetric case.

¹⁵Indeed, as shown in Voudon (2019), the closer to its precommitment timing a firm adopts (hence the later it adopts), the higher the profits.

¹⁶To see this, one can compute $\int_0^Q (a - t)dt - (a - Q)Q$.

6.1 Merger Regulation under the Precommitment game.

A first step is then to compare consumers' surplus under the different *laissez-faire* equilibria. However, under the precommitment game, the equilibrium selection issue arises again here: it is impossible for the competition authority to predict which firm will be the technology leader, and therefore to estimate consumers' surplus. I adopt then the same approach as for the merger game and I use the probabilities computed for the firms' mixed strategy in order to obtain for each case an expected consumers' surplus. Therefore, the consumers' surplus for the vertically separated case, the vertically integrated case and the asymmetric case¹⁷ respectively can be written as follow.

$$CS_{VS} = p_{VS}p_{VS}cs_{VS}^{11} + 2p_{VS}(1 - p_{VS})cs_{VS} + (1 - p_{VS})(1 - p_{VS})cs_{VS}^{22}$$

$$CS_{VI} = p_{VI}p_{VI}cs_{VI}^{11} + 2p_{VI}(1 - p_{VI})cs_{VI} + (1 - p_{VI})(1 - p_{VI})cs_{VI}^{22}$$

$$CS_{AC} = p_{AI}p_{AS}cs_{AC}^{11} + p_{AI}(1 - p_{AS})cs_{AI} + (1 - p_{AI})p_{AS}cs_{AS} + (1 - p_{AI})(1 - p_{AS})cs_{AC}^{22}$$

It is then possible to compare the different consumers' surplus, to determine which situation is preferred by consumers. However, here as well, such a comparison involves a non-analytical solution: a graphical solving is therefore used, under the same parametrization as the merger game. Graphical exposition is presented in Figure 13.

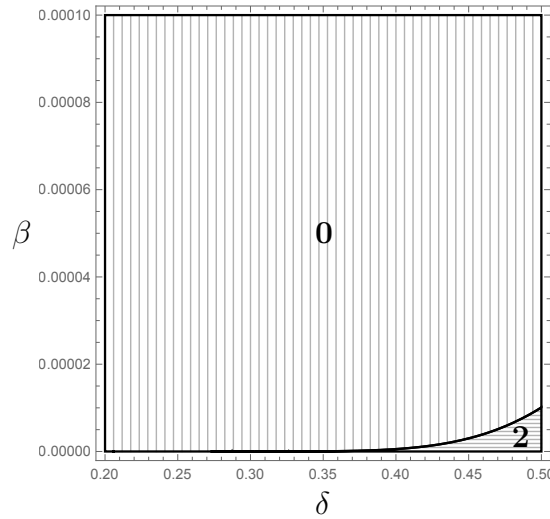


Figure 13: Number of integrations maximizing Consumers' Surplus: 0, 2

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.42$. This graph is restricted to values of β below 10^{-4} and values of δ above 0.2 for readability, as the rest of graph is unambiguously covered by the 0 area. For the values of β and δ inside the 0 area, the vertically separated case is preferred by consumers. For the values of β and δ inside the 2 area, the vertically integrated case is preferred by consumers.

For the current parametrization, the vertically separated case seem to be preferred by

¹⁷For the asymmetric case, I apply also the same strategy developed in Appendix A.2.

consumers most of the time, and the vertically integrated case may be preferable for very extreme values of β and δ .

Proposition 2. *Under the precommitment game, when the adoption cost is slowly decreasing with time and firms are patient, integration generally decreases the consumers' welfare: the symmetric vertically separated outcome is preferred by consumers for most parameter values. The vertically integrated case maximizes consumers' surplus only if the upstream bargaining power is extremely low and the effectiveness of the technology very high.*

The intuition for this result is as follow. From the consumers' point of view, the preferred market set-up is the one yielding the highest output. Using Table 1, one can compute the total quantities under the different set-ups and different timings of adoption. In particular, let's focus on the area located at the bottom right-hand corner of Figure 13: in this area, the only existing equilibrium in the asymmetric case is the one where firm *AI* leads. Let's write the total per-period quantities under the three set-ups for this area.

$$\begin{aligned}
Q_{VS}^0 &= \frac{4}{5}M & Q_{AC}^0 &= \frac{3}{4}M & Q_{VI}^0 &= \frac{2}{3}M \\
Q_{VS}^1 &= \frac{2}{5}M(2 + \delta) & Q_{AC}^1 &= \frac{1}{4}M(3 + 2\delta) & Q_{VI}^1 &= \frac{1}{3}M(2 + \delta) \\
Q_{VS}^2 &= \frac{4}{5}M(1 + \delta) & Q_{AC}^2 &= \frac{3}{4}M(1 + \delta) & Q_{VI}^2 &= \frac{2}{3}M(1 + \delta)
\end{aligned}
\tag{10} \tag{11} \tag{12}$$

where the subscript indicates the market set-up and the superscript the number of firms that have adopted the technology.

Assuming for now that the timings of adoption was the same under the three set-ups, clearly, $Q_{VS} \geq Q_{AC} > Q_{VI}$. Already, this is a clear reason why the vertically separated case is most of the time preferred by consumers: due to the *strategic* effect, both upstream firms choose below-cost wholesale pricing, pushing up the quantities produced by downstream firms.

However, the vertically integrated can still be preferable than the two other set-ups, for the parameter values depicted in the second graph of Figure 13. This possibility comes from the timing of adoption. For all set-ups, one must notice that $Q^2 > Q^1 > Q^0$ whenever $\delta > 0$. Therefore, the consumers' preferred timing of adoption would be that both firms adopt at the same time and as early as possible. From Voudon (2019), I know that for area 2 depicted in Figure 13, both adoptions occur earlier under the vertically integrated case, compared to the asymmetric case and the vertically separated case. In addition, one must notice that for high δ , the total quantity produced under the vertically integrated case when one or two firms have adopted is higher than the one of the vertically

separated case or the asymmetric case when no one has adopted. Thus, area 2 corresponds to the parameter values for which the adoption occurs much earlier under the vertically integrated case than any other set-up, yielding higher quantity and more surplus for the consumers. Ultimately, the fact that the vertically integrated case is preferred by consumers for this area compared to the asymmetric case is also due to the possibility of simultaneous adoption at T_1^{VI} : with probability p_{VI}^2 , both firms adopt very early under the vertically integrated case, whereas simultaneous adoption never occurs for such parameter values under the asymmetric case.

If the objective of a competition authority is to maximize consumers' surplus, it should forbid any integration unless the technology is very effective and the upstream bargaining extremely low. In more concrete terms, competition authorities should promote vertical separation unless this scenario involves very late technology adoptions, in which case these would probably happen earlier if both firms were integrated. In all cases, the asymmetric case is never maximizing the consumers' welfare, hence making the suspicion of competition authorities towards this set-up justified.¹⁸

What if the objective of the competition authority is to maximize social welfare? One can wonder what is the optimal number of integrations from a social welfare point of view, including consumers and both firms. The calculation of the social welfare is therefore quite straightforward, and consists in the addition of the different expected pay-offs computed previously.

$$SW = CS + \Pi_A + \Pi_B$$

where both profits and consumers' surplus are the expected ones.

Again, a graphical exposition is presented below, in Figure 14. The pattern is the same as for the merger game: the socially optimal number of integrations is 0 in the area 0, 1 in the area 1, and 2 in the area 2.

Hence, one can see that the Figure 14 is quite similar to Figure 13: the different areas slightly changed in size, but not in location. I state proposition 3.

Proposition 3. *Under the precommitment game, when the adoption cost is slowly decreasing with time and firms are patient, it is socially optimal that no integration occurs unless the upstream bargaining power β is low and the effectiveness of the new technology δ is high. The first integration increases social welfare when the effectiveness of the new technology is sufficiently high and for moderately low values of β , while the second integration for extremely low values of β .*

Let's discuss the mechanisms behind this result. A socially optimal set-up is a situation

¹⁸The previous results are robust to changes in α , M and r . Replications of Figure 13 under different parametrization are presented in Appendix A.3

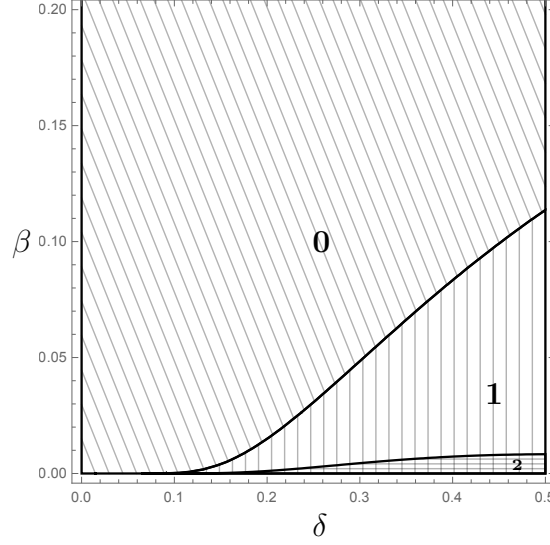


Figure 14: Number of integrations maximizing Social Welfare: 0, 1, 2

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.42$. This graph is restricted to values of β below 0.2 for readability, as the rest of graph is unambiguously covered by the 0 area. For the values of β and δ inside the 0 area, the vertically separated case is socially optimal. For the values of β and δ inside the 2 area, the vertically integrated case is socially optimal. For the values of β and δ inside the 1 area, the asymmetric case is socially optimal.

that reaches the best trade-off between maximizing the consumers' surplus on the one hand and the industry profits on the other hand. From the previous proposition I know what consumers prefer. In terms of total profits, the ranking is fairly straightforward (for the area considered where the only equilibrium in the asymmetric case is the one where AI leads): the industry profits are higher under the vertically integrated case than under the asymmetric case, which are higher than those under the vertically separated case, for all parameter values.¹⁹ Thus, one can observe that the preferences of the consumers and the industry are in conflict. The balance of these preferences yield the areas depicted in Figure 14.

Finally, the comparison of the areas depicted in Figure 10 and 14 allows me to determine whether the market naturally reach the socially optimal outcome. Answering this question involves comparing the areas of Figure 14 and the ones of Figure 10. Such comparison shows that area 1 of Figure 10 is smaller and included in area 1 of Figure 14, whereas area 0 and area 2 of Figure 14 are smaller and included the ones of Figure 10 respectively. Thus, I state the Corollary 1.

Corollary 1. *Under the precommitment game, when the adoption cost is slowly decreasing with time and firms are patient:*

- *Whenever the market is naturally selecting the asymmetric set-up, it is socially*

¹⁹Such statement involves graphical solving, but since the intuition is simple, graphical exposition is skipped.

optimal to do so.

- *Whenever the vertically separated case is socially optimal, the market will naturally select this set-up.*
- *Whenever the vertically integrated case is socially optimal, the market will naturally select this set-up.*

The reciprocal of these statements are not true.

Overall, Corollary 1 implies the competition authority should only intervene for the specific parameter values for which the asymmetric case would be optimal and is not naturally selected by the market. This implies promoting the first integration in the area 1 of Figure 14 overlapping the area 0 of Figure 10 and preventing the second integration in the area 1 of Figure 14 overlapping the area 2 of Figure 10.²⁰

6.2 Merger Regulation under the Preemption game.

Using the same definitions of consumer surplus and social welfare, I can now derive the policy implications under the preemption game. Using the timings derived in Voudon (2019), I can compute consumer surplus and social welfare regardless of equilibrium selection issues, as only timings are needed for the first one, and both payoffs are included for the second one.

Concerning the consumer surplus, the answer is clear: the consumer always prefer the vertically separated case. This holds for the current parametrization ($\alpha = 0.8$) but also for other ones.²¹ I state the following proposition.

Proposition 4. *Under the preemption game and the specific parametrization where $M = 1$, $\alpha = 0.6$ and $r = 0.03$, integration always decreases the consumers' welfare: the symmetric vertically separated outcome is preferred by consumers for all parameter values.*

The possibility of simultaneous early adopting that existed in the precommitment game does not exist here anymore. Hence, vertical separation driving both high quantities and early adoptions due to strong preemption incentive, is the preferred set-up of consumers.

Concerning social welfare, the conclusion is more complex. Figure 15 represents the different parameter values for which a set-up is socially preferred or not.

I state the following proposition.

²⁰The previous results are robust to changes in α , M and r . Replications of Figure 14 under different parametrization are presented in Appendix A.3

²¹See Appendix A.3.

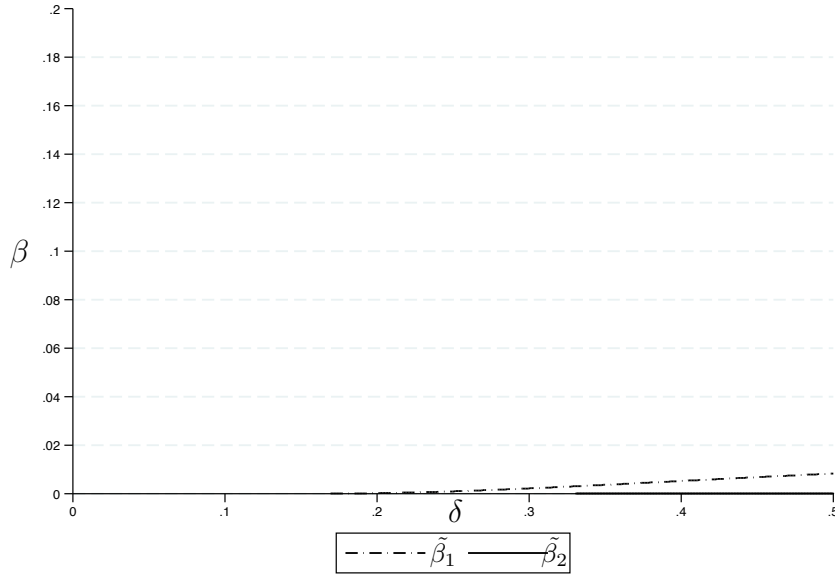


Figure 15: Social Welfare under preemption

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. For readability, values above $\beta = 0.2$ are not represented, as they are not informative. The two thresholds delimit the three types of equilibria. Above $\tilde{\beta}_1$, society prefers the vertically separated case. Below $\tilde{\beta}_2$, society prefers the vertically integrated case. Between $\tilde{\beta}_1$ and $\tilde{\beta}_2$, the asymmetric set-up is preferred.

Proposition 5. *Under the preemption game, when the adoption cost is slowly decreasing with time and firms are patient, it is socially optimal that no integration occurs unless the upstream bargaining power β is low and the effectiveness of the new technology δ is high. The first integration increases social welfare when the effectiveness of the new technology is sufficiently high and for moderately low values of β , while the second integration increases it for extremely low values of β .*

The graph and intuition is qualitatively similar to the precommitment game. The balance of consumers' preference for the vertically separated case and the preferences of the two firm yields the previous outcome. Now I compare the Figure 15 and the Figures 11 and 12, in order to see whether the merger game outcomes match the socially preferred ones. I state the following Corollary.

Corollary 2. *Under the preemption game, when the adoption cost is slowly decreasing with time and firms are patient:*

- *Under the Hypothesis 1:*
 - *Whenever the market naturally selects the vertically separated case, it is socially optimal to do so.*
 - *Whenever the vertically integrated case is socially optimal, the market will naturally select this set-up.*
 - *When the market selects the asymmetric set-up, it is optimal to do so for a*

very small range of parameter values.

- *Under the Hypothesis 2:*
 - *Whenever the vertically separated case is socially optimal, the market will naturally select this set-up.*
 - *Whenever the vertically integrated case is socially optimal, the market will naturally select this set-up.*
 - *The market never selects the asymmetric set-up, whereas it would be optimal to do so for some parameter values.*

The reciprocal of these statements are not true.

Let's discuss Corollary 2. Under Hypothesis 2, the asymmetric case is never chosen by the market, whereas society would prefer it for some range of parameters. Hence, for such parameters' range, competition authorities should promote integration when both firms are choosing to be separated, and should prevent one of the integrations when both firms want to integrate.

Under Hypothesis 1, the asymmetric case occurs but not for the right parameter values, according to social welfare. The market tends to choose the asymmetric case whereas the society would prefer firms to remain separated, and the market tends to choose the vertically integrated case whereas the society would prefer one firm to remain separated. For a small range of parameter values, market and society's preferences are aligned. Henceforth, the appropriate competition policy is qualitatively similar to Hypothesis 2.

To summarize, this section indicated two types of competition policy. The first, considering only consumers' surplus, should prevent any integration most of the time (apart from very extreme cases where two integrations should occur). The second one, considering social welfare, should most of the time adopt a *laissez-faire* position, apart from some cases where the promotion or the prevention of one integration is socially optimal.

7 Conclusion

Throughout this chapter, I developed a technology adoption model in a vertically structured set-up. The combination of such features in a merger game yielded novel results about the optimality of a given vertical structure.

Combining the features of a merger game and a precommitment game, I proved the existence of an asymmetric equilibrium, where one firm choose to integrate while the other one remains separated, in a purely symmetric set-up, without any synergies or

foreclosure incentives. More specifically, I discussed the impact of such integration on both per-period profits and timing of adoption, and demonstrated that the profitability of integration purely stems from the possibility to become a profitable technology leader.

I explored the combination of merger game and preemption, which proved being very difficult due to the nature of such adoption game. Still, I was able to draw some intuitions, where the asymmetric set-up could be reached under *laissez-faire* due to the possibility to avoid preemption.

Finally, from a competition policy perspective, I determined whether a competition authority should prevent integration or not. Considering consumers' surplus only, such competition authority should generally prevent integration, but if it considers social welfare, on the contrary, it should not intervene most of the time. The policy implication is qualitatively similar whether I consider the preemption or the precommitment game.

Overall, the claim of this paper is to show that, on the one hand, the presence of innovative processes in an industry considerably affects its vertical structure, and on the other hand, the shape of the vertical relations in an industry determines its performance in innovative terms. Hence, this work support the view that competition authorities should adopt a more "effect-based" approach.

Indeed, competition authorities tend to view integrations suspiciously due to their capacity to reduce competition, notably by creating hold-up or cartel incentives. As a result, their grounds of investigation and exemptions are mainly focused on final prices faced by consumers. In this work, I suggest that such investigations in an innovative industry should take into account the technology adoption decisions of firms and their impact on consumers' surplus. Carefully studying both market's and technology's characteristics, a competition authority is able to assess whether a firm's decision to integrate harms consumers' welfare, or simply whether such decision is motivated by anticompetitive purposes.

A Appendix

A.1 Graphs: Pure Strategy Equilibria

In this Appendix subsection, I investigate the integration game equilibria using pure strategies only, under the precommitment game. Hence, I assume full anticipation of the agents: I compute the equilibria assuming that each firm know which technology position it will have, in all vertical set-ups. In the following figure, I show the profitability areas for integration when the competitor is separated, and integration when competitor is

integrated, for all the possible technology positions. Since I am focusing on an area where the only equilibrium in the asymmetric case is the one where the integrated firm is the leader, I consider only this set-up in the following graph.²²

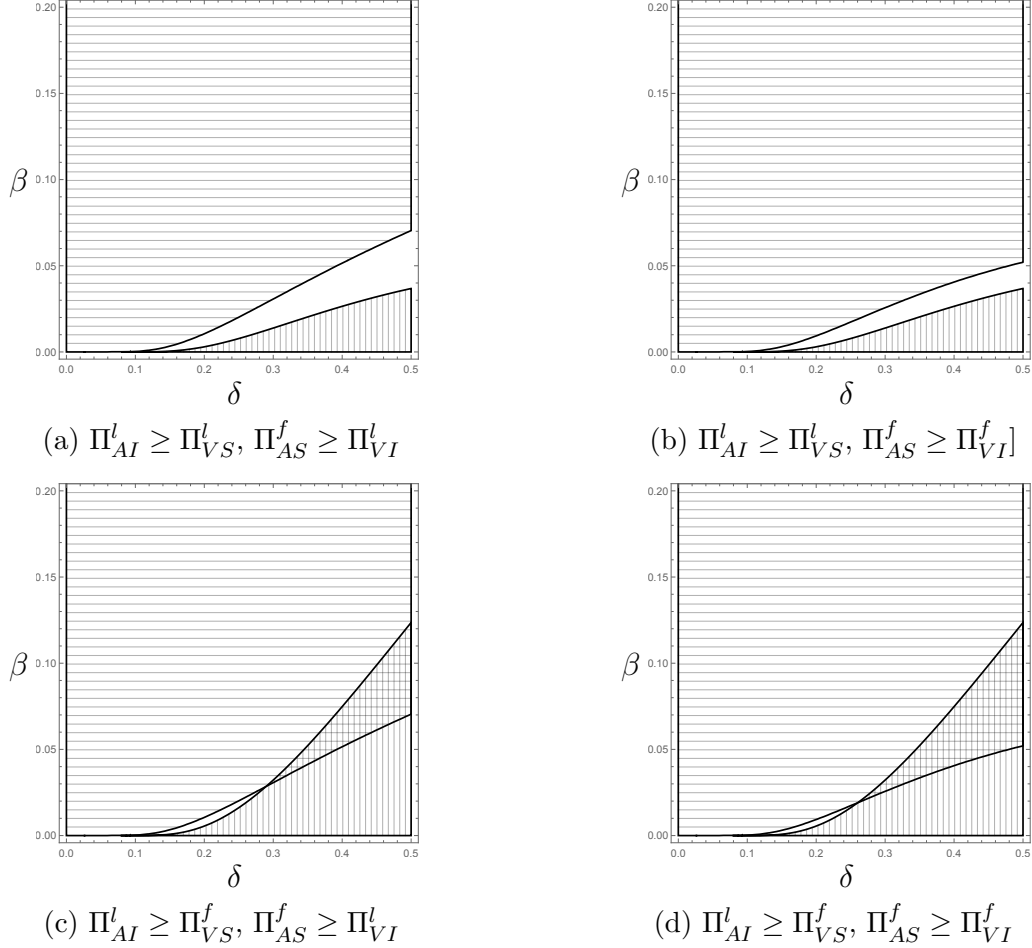


Figure 16: Profitability of Integration under Pure Strategies

Note: In this graph, the parametrization is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.42$. This graph is restricted to values of β below 0.2 for readability, as the rest of graph is unambiguously covered by the horizontally stripped area. For the values of β and δ in the vertically stripped area, integration is profitable when the competitor is separated. For the values of β and δ in the horizontally stripped area, integration is not profitable when the competitor is integrated.

The asymmetric equilibrium exists only if both areas are overlapping. For the blank areas, uncovered by stripes, the vertically integrated outcome happens (see section 4.2.3 for details). Hence, from these graphs, the asymmetric equilibrium exists only if the firms fully anticipates to be the follower in the vertically separated case. Such results are rather trivial, because they depend on the full anticipation assumption. The previous statement simply says that if the firm expects to not be a separated profitable technology leader, it will prefer to become an integrated profitable technology leader: the result is implied

²²This is because the profitability area of integration is always located in the bottom right hand corner of the graph, where the only asymmetric equilibrium is the one where AI leads.

by the assumption. This is why I prefer to investigate the mixed strategy equilibrium. Analyzing the pure strategies is still informative as it actually shows that the results obtained using the mixed strategy equilibrium are not qualitatively different from the ones obtained considering pure strategies.

A.2 Discussion: the equilibrium selection in the asymmetric case.

In this appendix section, I will detail my equilibrium selection strategy for the asymmetric case under the precommitment game. In the symmetric cases, using the mixed strategy equilibrium is a rather straightforward procedure, as the equilibria existed for all parameter values, and the timings of adoption were identical for both firms.

In the asymmetric case, the existence of the pure strategy equilibria and the difference in terms of timing between the situation where *AI* leads and the where *AS* leads depend on the parameter values. Figure 17 depicts the ranges of parameter values characterizing the possible situations.

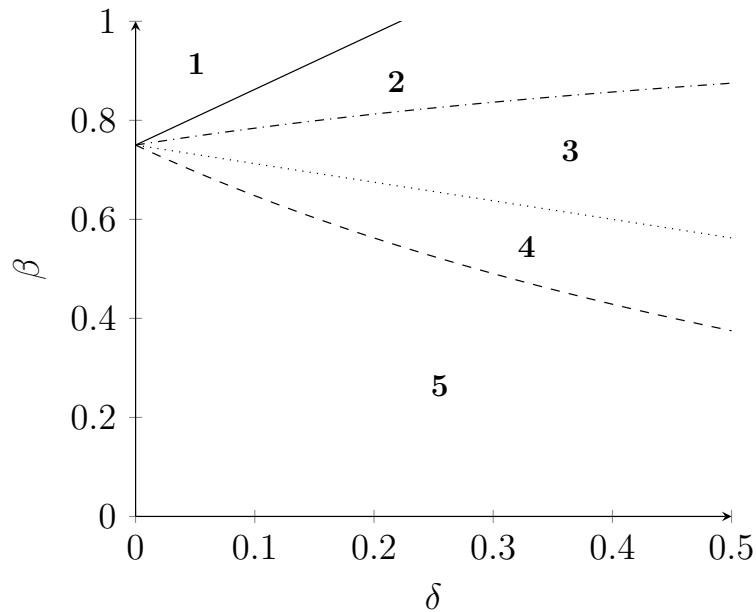


Figure 17: Asymmetric Case: Timing of Adoption

In zone 1, the only existing equilibrium in pure strategy is the one where firm *AS* leads. In such case, firm *AS* necessarily plays T_1^{AS} and firm *AI* necessarily plays T_2^{AI} . Therefore, $\Pi_{AS} = \Pi_{AS}^1$ and $\Pi_{AI} = \Pi_{AI}^2$ for zone 1.

Similarly, in zone 5, the only existing equilibrium in pure strategy is the one where firm *AI* leads. Then, firm *AI* necessarily plays T_1^{AI} and firm *AS* necessarily plays T_2^{AS} . Thus, $\Pi_{AI} = \Pi_{AI}^1$ and $\Pi_{AS} = \Pi_{AS}^2$ for zone 5.

From Voudon (2019), I know that both equilibria in pure strategies (*i.e.* where firm *AI* leads and where *AS* leads) exist for the area 2, 3 and 4. The black lines separating these zones indicates the parameter values for which $T_1^{AI} = T_1^{AS}$ (the upper line) and for which $T_2^{AI} = T_2^{AS}$ (the lower line).

In zone 2, $T_1^{AI} > T_1^{AS}$ and $T_2^{AI} > T_2^{AS}$. In such case, the issue that may arise is that $\Pi_{AI}^1 < \Pi_{AI}^{22}$ (meaning that *AI* would always choose T_2^{AI}) or that $\Pi_{AS}^{U2} < \Pi_{AS}^{U11}$ (meaning that *AS* would always choose T_1^{AS}). Such possibility arises because, even if both firms adopt “at the same time” (*i.e.* both choose T_1 or both choose T_2), one remains the technology leader and the other one the technology follower. If the comparison of the profits is clear between two situations where the firm has the same technology position,²³ such comparison between profits where the firm is the leader in one and the follower in the other, is less obvious, and depends on parameter values.²⁴ Indeed, whenever $\Pi_{AI}^1 < \Pi_{AI}^{22}$, *AI* will always choose T_2^{AI} : therefore, *AS*’s best response is to always choose T_1^{AS} . Reversely, whenever $\Pi_{AS}^{U2} < \Pi_{AS}^{U11}$, *AS* will always choose T_1^{AS} : therefore, *AI*’s best response is to always choose T_2^{AI} . Thus, in zone 2, whenever $\Pi_{AI}^1 < \Pi_{AI}^{22}$ or $\Pi_{AS}^{U2} < \Pi_{AS}^{U11}$, the pure strategy equilibrium in which *AS* leads is the only existing one: in such case, $\Pi_{AS} = \Pi_{AS}^1$ and $\Pi_{AI} = \Pi_{AI}^2$. Otherwise, in zone 2, Π_{AS} and Π_{AI} will take their expected pay-off form, presented in Equation (5).

I repeat the same reasoning for zone 3 and zone 4.

In zone 4, $T_1^{AI} < T_1^{AS}$ and $T_2^{AI} < T_2^{AS}$. Hence, whenever $\Pi_{AS}^{U1} < \Pi_{AS}^{U22}$ or $\Pi_{AI}^2 < \Pi_{AI}^{11}$, the pure strategy equilibrium in which *AI* leads is the only existing one: in such case, $\Pi_{AI} = \Pi_{AI}^1$ and $\Pi_{AS} = \Pi_{AS}^2$. Otherwise, in zone 4, Π_{AS} and Π_{AI} will take their expected pay-off form, presented in Equation (5).

In zone 3, $T_1^{AI} < T_1^{AS}$ and $T_2^{AI} > T_2^{AS}$. Hence, whenever $\Pi_{AI}^1 < \Pi_{AI}^{22}$ and $\Pi_{AI}^2 > \Pi_{AI}^{11}$, the pure strategy equilibrium in which *AS* leads is the only existing one: in such case, $\Pi_{AS} = \Pi_{AS}^1$ and $\Pi_{AI} = \Pi_{AI}^2$. Whenever $\Pi_{AI}^1 > \Pi_{AI}^{22}$ and $\Pi_{AI}^2 < \Pi_{AI}^{11}$, the pure strategy equilibrium in which *AI* leads is the only existing one: in such case, $\Pi_{AI} = \Pi_{AI}^1$ and $\Pi_{AS} = \Pi_{AS}^2$. Otherwise, in zone 3, Π_{AS} and Π_{AI} will take their expected pay-off form, presented in Equation (5).

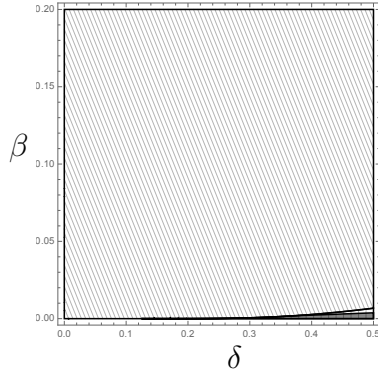
Finally, I obtained a single pay-off Π_{AS} and Π_{AI} for every zone depicted in Figure 17. The comparison of such pay-off with the ones of the vertically separated and integrated case is possible, allowing then the solving of the merger game.

²³The profits as a leader (follower) are strictly concave in time, and T_1 (T_2) is the only global maximum.

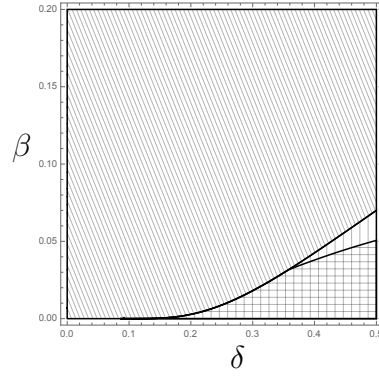
²⁴As in section 4.2, an analytical solution can’t be provided about such profits comparison.

A.3 Graphs: Impact of α , M and r

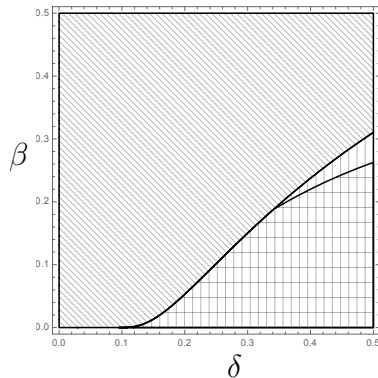
α corresponds to the speed at which the adoption costs decrease. A lower α makes the adoption costs fall slower. The main impact of alpha is to affect the timing of adoption and the adoption costs. Consequently, a lower alpha tends to make the timing difference between two set-ups larger. Therefore, the only effect of a too large α is to make the “positive conditions” previously described very small, without affecting the existence of any of the three possible equilibria. M , the market capacity, affects both timings and per-period profits in the same way for all market set-up. The only qualitative impact of this parameter is to set the lower bound value of α . r is the interest rate, and determines the value given by firms to future streams of profits. It also affects the adoption costs function, and therefore the timing of adoption. It may change slightly the shape of the positive zones depicted before, but it doesn’t affect qualitatively the previous interpretations and results.



(a) $M = 1$, $\alpha = 1$ and $r = 0.03$



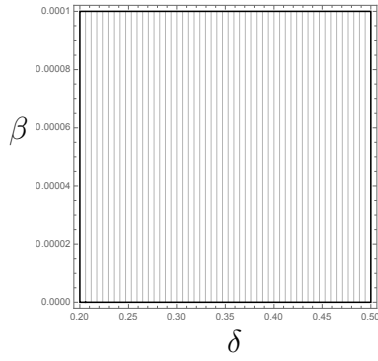
(b) $M = 0.5$, $\alpha = 0.42$ and $r = 0.03$



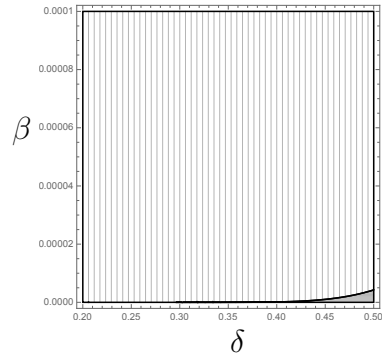
(c) $M = 1$, $\alpha = 0.42$ and $r = 0.1$

Figure 18: Number of Integrations under Different Parametrizations

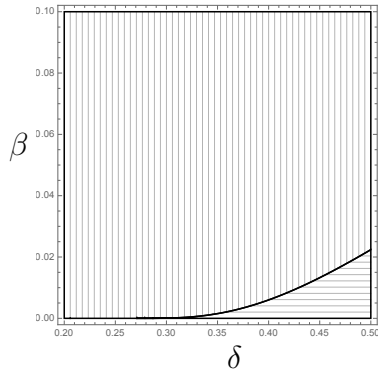
Note: These graphs are replications of Figure 10 under different parametrizations.



(a) $M = 1$, $\alpha = 1$ and $r = 0.03$



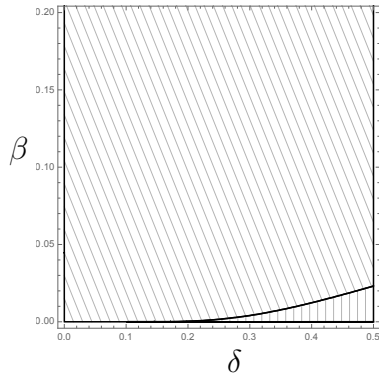
(b) $M = 0.5$, $\alpha = 0.42$ and $r = 0.03$



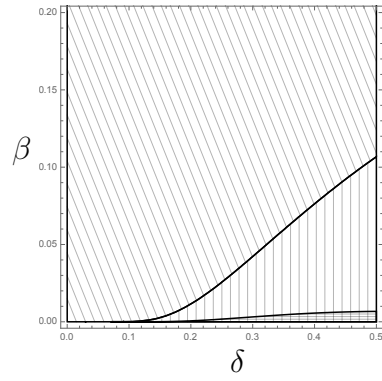
(c) $M = 1$, $\alpha = 0.42$ and $r = 0.1$

Figure 19: Consumers' Surplus under Different Parametrizations

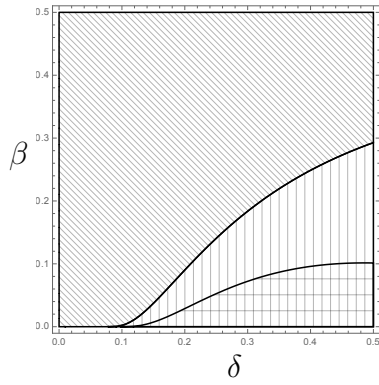
Note: These graphs are replications of Figure 13 under different parametrizations.



(a) $M = 1$, $\alpha = 1$ and $r = 0.03$



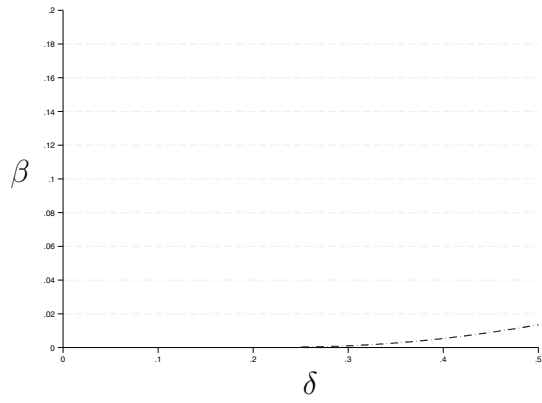
(b) $M = 0.5$, $\alpha = 0.42$ and $r = 0.03$



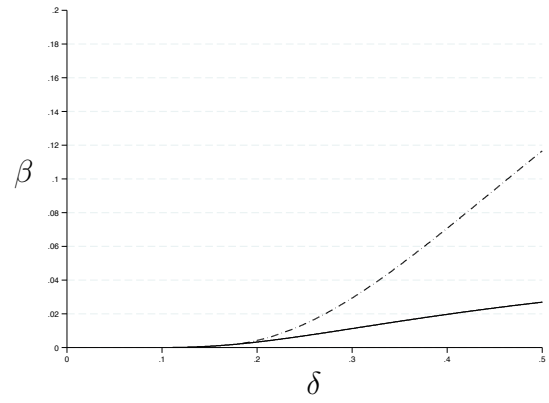
(c) $M = 1$, $\alpha = 0.42$ and $r = 0.1$

Figure 20: Social Welfare under Different Parametrizations

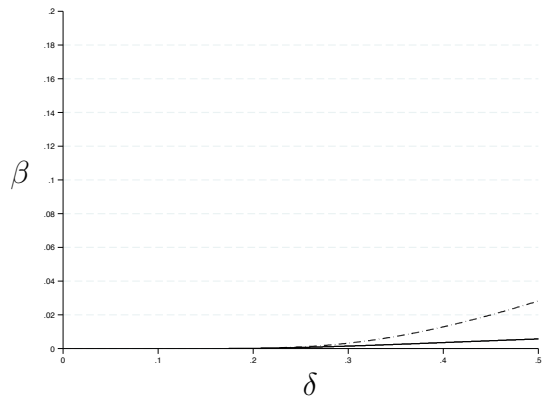
Note: These graphs are replications of Figure 14 under different parametrizations.



(a) $M = 1$, $\alpha = 1$ and $r = 0.03$



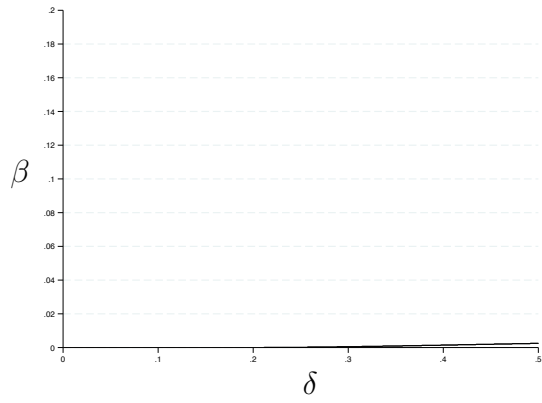
(b) $M = 1$, $\alpha = 0.8$ and $r = 0.05$



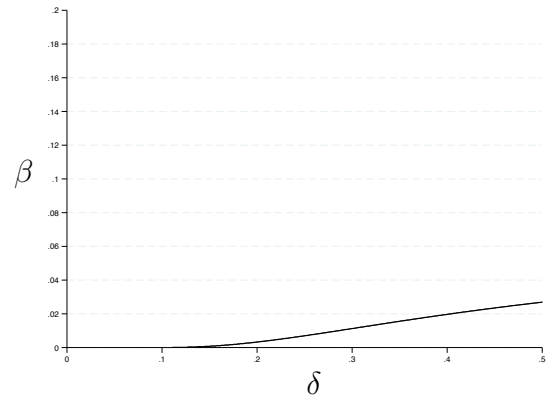
(c) $M = 0.5$, $\alpha = 0.8$ and $r = 0.03$

Figure 21: Merger Game Equilibria under Preemption - Hypothesis 1

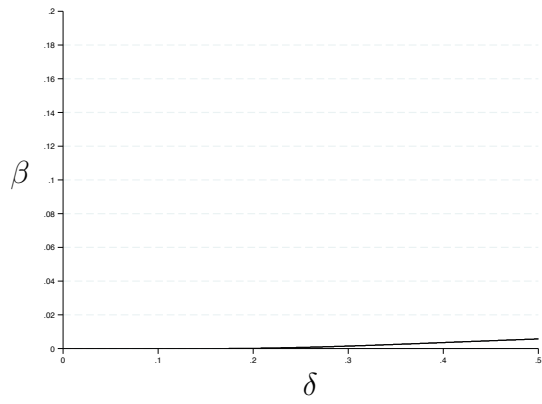
Note: These graphs are replications of Figure 11 under different parametrizations.



(a) $M = 1$, $\alpha = 1$ and $r = 0.03$



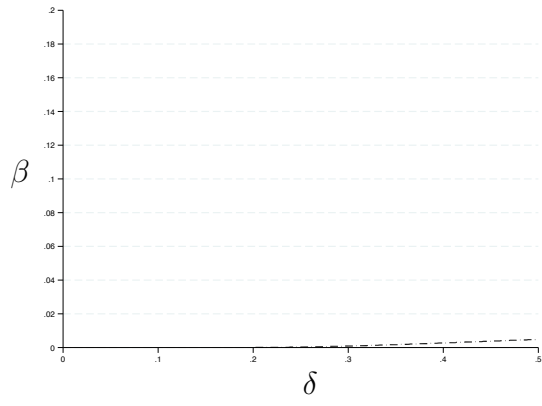
(b) $M = 1$, $\alpha = 0.8$ and $r = 0.05$



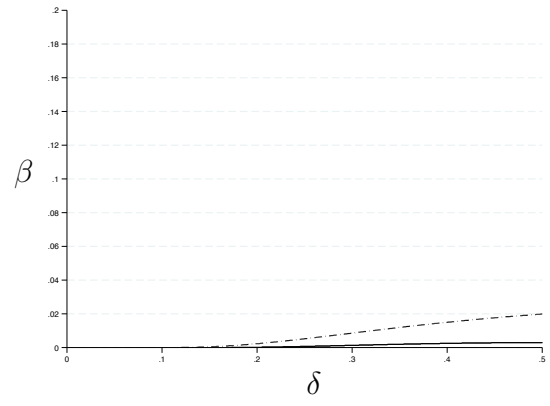
(c) $M = 0.5$, $\alpha = 0.8$ and $r = 0.03$

Figure 22: Merger Game Equilibria under Preemption - Hypothesis 2

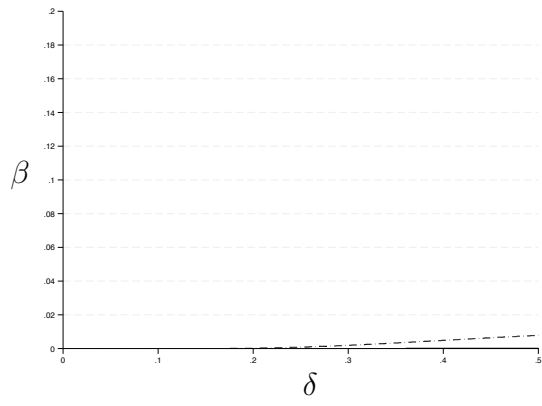
Note: These graphs are replications of Figure 12 under different parametrizations.



(a) $M = 1$, $\alpha = 1$ and $r = 0.03$



(b) $M = 1$, $\alpha = 0.8$ and $r = 0.05$



(c) $M = 0.5$, $\alpha = 0.8$ and $r = 0.03$

Figure 23: Social Welfare under Preemption

Note: These graphs are replications of Figure 15 under different parametrizations.

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