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**ESSAYS IN INDUSTRIAL ORGANISATION:
MARKET STRUCTURE, NON-PRICE
STRATEGIES AND WELFARE.**

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BY

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Declaration

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Summary

This dissertation consists of three essays in industrial organisation theory. It examines the relationship between market structure, welfare and firms' non-price strategies. In particular, it theoretically explores, on the one hand, how the structure of a market affects the incentives of firms to undertake certain types of investments, and on the other hand, how such investments may in turn have an impact on market structure and welfare.

The first essay (Chapter 1) discusses the impact of the level of vertical integration on the timing of adoption of a cost-reducing technology. Combining the technology adoption and vertical relations literatures in a simple duopoly model, I compare the technology adoption patterns under different exogenous vertical structures. In particular, the study of the asymmetric case, where one firm is integrated while the other one is separated, allows me to make three main contributions. First, I show that the influence of vertical integration on the technology adoption decision by one firm is significantly influenced by the vertical structure of the other firm. Second, I consider the two main types of technology adoption games under an asymmetric set-up and broaden the understanding of the underlying mechanisms for the solving of such games. Finally, I develop an industrial policy aimed at encouraging firms to adopt the technology at the socially optimal timing.

The second essay (Chapter 2) is a continuation of Chapter 1 as it examines vertical integration incentives in the presence of a cost-reducing technology. The vertical integration decision is now endogenous. Using the same model, I show that even in a purely symmetric set-up with no synergies or foreclosure incentives, an asymmetric integration equilibrium in which only one firm chooses to vertically integrate can arise. Against the backdrop of this overall contribution, this essay makes three specific contributions. First, I show that vertical integration is profitable whenever it will allow the firm to adopt the technology faster and 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, I show that while vertical integration generally reduces consumer

surplus, the market often maximises societal welfare.

The third essay (Chapter 3) develops a theoretical framework in order to understand the impact of the competition of heterogeneous retailers (internet versus brick-&-mortars) on market structure, profits, consumer surplus and societal welfare. The introduction of internet retailing radically changed shopping habits, and these new consumption patterns directly affect firms' strategies, incentives and payoffs. In this context, I develop a theory of predatory investment. First, I show that a patient online retailer may find it profitable to invest aggressively in delivery services and lower its price in order to exclude a physical competitor from the market. Second, I show that such strategy is particularly profitable if the online firm is allowed to build its own physical store in a densely populated area post-exclusion. Finally, I show that, while consumers benefit from such predatory strategy when they are sufficiently impatient, society is generally worse off.

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*à mon ami, Jean-Pierre
à ma grand-mère, Christiane*

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General Introduction

Patience et longueur de temps
Font plus que force ni que rage.

Jean de la Fontaine
Le Lion et le Rat (1668)

This dissertation is composed of three essays in Industrial Organisation Theory. A common theme running through these essays is the exploration of the relationship between the structure of a market (i.e. the number of competitors, their vertical structure) and the firm's incentives to undertake non-price strategies (e.g. innovation, investments). The first two chapters focus more specifically on technology adoption and vertical structure, whereas the last one focuses on retail market structure and investment in delivery services. I theoretically investigate, on the one hand, how the structure of a market influences the incentives of firms to undertake investments, and on the other hand, how such investment may impact on market structure and welfare.

Another common theme of these essays is patience. Often, non-price strategies may be costly today and profitable in the future, and a firm's incentives to undertake them consequently depends on its patience and its medium to long-run profits. The first two chapters discuss the timing of adoption of a cost-reducing technology and how such long-term decisions are affected by the vertical structure of the market, and how these affect firm's choice to become vertically integrated. The third chapter demonstrates how a firm may find it profitable to undertake very costly short-run delivery services (e.g. Amazon Prime) for future monopoly profits, when it is patient enough.

In the first essay (Chapter 1), I discuss the impact of vertical integration on the timing of adoption of a cost-reducing technology. I develop a duopoly model in which two vertical chains (i.e. an upstream firm and a downstream firm) compete in quantity. When the vertical chains are separated, upstream and downstream partner bargain over a two-part tariff (i.e. a fixed fee and a wholesale price) according to a Nash bargaining problem. In the first stage of the game, upstream firms decide when

to adopt a cost-reducing technology. The second stage is the contract negotiation and the third stage is the quantity competition. Hence, I combine two literatures in a single model: the technology adoption literature (with the seminal papers of Reinganum (1981b) and Fudenberg and Tirole (1985)) and vertical relations literature (with the seminal paper of Bonanno and Vickers (1988)). In this chapter, I compare the technology adoption patterns under different exogenous vertical structures: one in which both firms are separated, one in which both are integrated, and one in which only one firm is integrated (i.e. the so-called asymmetric case).

In particular, the study of the asymmetric case allows me to make three main contributions. First, I show that the effect of vertical integration on technology adoption by one firm is significantly influenced by the vertical structure of the other firm. This is due to the combination of two effects: the *bargaining* effect and the *strategic* effect. The *bargaining* effect relates to the fact that, if the bargaining process is disadvantageous to the upstream firm when separated, it will have stronger incentives to adopt the technology once integrated, since integration resolves this hold-up issue. The *strategic* effect relates to the fact that when separated, wholesale price is set below cost, such that the sum of upstream and downstream profits is maximised. Hence, when upstream bargaining power is high, incentives to adopt the technology are stronger when the firm is separated. Finally, if the competitor is separated, integration by one firm affects the contract negotiation occurring between upstream and downstream competitors; this amplification effect linked to the *strategic* effect implies that the effect on integration on adoption speed depends on the vertical structure of the competitor.

Second, I consider the two main types of technology adoption games under an asymmetric set-up and broaden the understanding of the underlying mechanisms for the solving of such games. The precommitment game (developed by Reinganum (1981b)) assumes that both firms choose their adoption date at time $t = 0$ and commit to it. The preemption game (developed by Fudenberg and Tirole (1985)) assumes that firms can immediately react to each other's adoption choice at any point in time. In a symmetric set-up, these games always have different predictions, whereas in an asymmetric set-up, they can predict the same adoption patterns. This is due to the *preemption* effect: a firm will adopt later if the competitor has less incentives to preempt. In addition, the impact of integration on the timing of adoption do not differ qualitatively in the preemption game compared to the precommitment.

Finally, I develop an industrial policy aimed at encouraging firms to adopt the technology at the socially optimal timing. While consumers would enjoy immediate adoption (i.e. at $t = 0$), the competitor of the technology adopter would enjoy later adoption. The trade-off between these different incentives yield the socially

optimal timing of adoption, which can be earlier or later than the market's timing. Hence, I develop a taxation scheme in order to incentivise firms to adopt at the right time from society's point of view. However, such taxation scheme strongly depends on the type of adoption game. Overall, the aim of this essay is to disentangle the multiple mechanism driving the speed of technology adoption in vertically structured industries.

In the second essay (Chapter 2), I use the same model but endogenising the integration decision. In addition to the three stage aforementioned (i.e. adoption decision, contract negotiation and quantity competition, in that order), I let firms choose, in a first sequential stage, whether they prefer to remain separated, or become integrated. The aim of this chapter is to theoretically examine vertical integration incentives in the presence of a cost-reducing technology. I show that even in a purely symmetric set-up with no synergies or foreclosure incentives, an asymmetric integration equilibrium in which only one firm chooses to vertically integrate can arise.

Against the backdrop of this overall contribution, this essay makes three specific contributions. First, I show that vertical integration is profitable whenever it will allow the firm to adopt the technology faster and become a profitable technology leader for a longer period of time. Indeed, integration is profitable when upstream bargaining power is low, that is when the *bargaining* effect is strong: integration resolves the hold-up issue, and adoption occurs much faster. The scale of that mechanism depends on whether the competitor is integrated or separated, due to the amplification effect described before. There exists a range of parameter values for which this difference in incentives makes the asymmetric equilibrium arise.

Second, comparing preemption and precommitment game, I show that the asymmetric equilibrium may exist under both types of game. The solving of these two games is very different but describes the same mechanism: there exists a range of parameter values for which there is an incentive to integrate when the competitor is separated but there is not such an incentive when the competitor is separated. This result is derived from the analysis carried in Chapter 1.

Third, I show that while vertical integration generally reduces consumer surplus, the market often maximises societal welfare. Consumers prefer high output and quick adoption, which mostly occurs under vertical separation. However, a competition authority maximising social welfare should not intervene in such integration processes.

In the third essay (Chapter 3), I develop a theoretical framework in order to understand the impact of the competition of heterogeneous retailers (internet versus

brick-&-mortars) on market structure, profits, consumer surplus and societal welfare. Indeed, the recent dramatic increase in retailer closures raised serious questions about the responsibility of major Internet retailers, such as Amazon.com, in the so-called “Retail Apocalypse”. The introduction of internet retailing radically changed shopping habits, and these new consumption patterns directly affect firms’ strategies, incentives and payoffs. In particular, this essay tries to reconcile four stylized facts: the sharp increase of retailer closures; the non-profitability of Amazon for its first twenty-five years of existence (i.e. up to 2017); the immense cost of Amazon’s delivery policy (e.g. Amazon Prime); and the establishment of Amazon physical retailers since 2018 (e.g. Amazon 4-Star).

I build a model in which consumers choose between consuming a homogeneous product online or at a physical retailer. Visiting the shop allows them to experience (e.g. see, smell, touch) pre-purchase and to solve the ex-ante uncertainty they have about their valuation of the good. However, buying directly online allows them to save the transport cost to visit the shop, and generally allows them to obtain the product at a cheaper price. Consumers are differentiated in terms of their distance to the physical shop and terms of their patience for the delivery time. Depending on these two parameters, consumers may choose to buy directly online, to visit the shop and buy from it, or to visit the shop and buy online (or not buy). I study the competition of an online retailer and a physical retailer facing such a demand. They face the same marginal costs, but the online retailer can invest in delivery services in order to reduce the importance of patience in consumers’ preferences.

First, I study a one-period model of competition, and I compare the market’s outcomes when investments are allowed to the benchmark case where they are not allowed. My first result is to show that in a static game, an online firm chooses to invest relatively little in delivery services; prices and profits are very similar to those under the benchmark case.

Second, I study a two-period model of competition, and I investigate the profitability of different strategies of the online firm. In particular, I compare a predatory strategy, consisting in excluding the physical competitor using price and investment during the first period and enjoy monopoly profits during the second period, to an accommodation strategy, consisting in competing with the brick-&-mortar every period. I show that a sufficiently patient online retailer may find it profitable to invest aggressively in delivery services and lower its price in order to exclude a physical competitor from the market. Such a strategy is more costly as the probability of having a positive experience from the good increases.

Third, I compare two types of predation strategies: one in which the online firm

benefits from a monopoly over the online market only during the second period; and one in which the online firm builds its own physical store post-exclusion (the so-called predation with replacement). I show that the predation with replacement is more profitable than without. Building its own physical premises allows the online firm to capture an impatient and centrally located customer base it would not reach if it remained fully online.

Finally, I show that, if consumers are sufficiently impatient, they benefit from such a predatory strategy, especially with replacement. However, society is generally worse off as a result of predation.

In a last chapter, I draw a general conclusion.

Chapter 1

Technology Adoption under Asymmetric Market Structure

1.1 Introduction

The study of innovation and technology patterns is a fundamental area of Industrial Organisation. It drives the economic performance of a firm, a market, and more globally, of an economy. These processes are the core mechanisms of some growth models, as well as important features of competition models. Indeed, the competition economist must consider how some regulations and business practices may influence innovation. Such research activities, whether it takes the form of R&D expenses or technology adoption, may allow the consumer to access a better product at a better price. Hence, a practice that could have been assessed as anticompetitive according to standard price theories may be reevaluated as beneficial to the consumer if it promotes innovation. In this paper, I explore how the vertical structures of market participants affects the timing of technology adoption. In a market where a new cost-reducing technology is available, how does the vertical structure of the firms affect the adoption patterns?

Such technologies are costly to adopt for the firm, but they allow the adopter to produce its product at a lower cost, which is beneficial to the consumer as it leads to lower prices. Game theorists developed models in order to explain the adoption patterns of such a cost-reducing technology within a market. Reinganum (1981b) and Fudenberg and Tirole (1985) introduced the main two games exploited in the literature of technology adoption; namely, the precommitment game and the preemption game. Both models start with a symmetric duopoly set-up, and conclude on technology diffusion, whereby firms adopt the technology one after the other. However, the two games use different solution concepts: the precommitment one uses

Nash equilibrium while the preemption one uses subgame perfection. Their results differ in terms of pay-off; while there is a first mover advantage in the precommitment game, rent-equalisation occurs in the preemption game. The mechanism behind such models rely essentially on the trade-off between adopting early in order to preempt the competitor and adopting later due to the decreasing adoption cost function.

Many papers extended these models to more firms, but almost none of them explored the impact of different vertical structure on such adoption processes. Indeed, the capacity of an upstream firm to invest in a cost-reducing technology surely depends on its relationship with its downstream partner, and the degree of vertical integration definitely has an impact on the incentives to adopt such a technology. Alipranti et al. (2015) appears to be the only work comparing the timing of technology adoption under input outsourcing and input insourcing, and showing that the presence of a vertical dimension may affect the speed of adoption of a new technology. Since the timing of adoption depends on the increment to profits that the adopter gets from it, integration, affecting such profitability, may accelerate the speed of adoption when the adopter could not capture enough of the gains from adoption when separated, due to the inevitable profit-sharing between upstream and downstream firm.

I exploit many of their model's features and adapt them to an asymmetric set-up. Indeed, Alipranti et al. (2015) only compared a duopoly where either both firms are separated or both are integrated, and the only adoption game they exploited is the precommitment game of Reinganum (1981b). This paper extends their work by considering the asymmetric case where only one firm is vertically integrated, and using both precommitment and preemption game. Taking the vertical structure as exogenous,¹ I evaluate the impact of a single integration on the speed of adoption, and I see how such impact differs from a situation where the competitor is already integrated to a situation where it is separated. In addition, I can tell whether the type of technology adoption game affect these results. Such an investigation matters for competition policy purposes, as the competitive assessment of an integration in this context may be reconsidered and affected by the effect of such vertical merger on the timing of adoption.

In this chapter, I study a duopoly model, where two vertical structures compete in quantities. The upstream firm is the technology adopter, so the reader may think of it as an innovative producer dealing with a downstream retailer. Downstream firms compete *à-la* Cournot, and contract negotiation between upstream and downstream partners occurs according to a Nash bargaining program. The first stage of the game

¹In this work, I don't discuss the vertical merger decision in itself but its impact on the timing of technology adoption. In Chapter 2, I investigate the decision to integrate in a similar context.

is the technology adoption game, which can be either the precommitment game or the preemption game. I show that integration accelerates adoption whenever the upstream bargaining power is low and the efficiency of the technology is high, which is qualitatively unaffected by the type of adoption game. I highlight two main effects of integration: a *bargaining* effect and a *strategic* effect.

The *bargaining* effect stems from the profit-sharing occurring under separation between upstream and downstream partners. When its bargaining power is low, the upstream firm (*i.e.* the adopter) faces some kind of hold-up issue, as it cannot capture the full benefits from its investment in the cost-reducing technology. In such a context, integration allows the adopter to capture the full benefits from the technology adoption.

The *strategic* effect comes from the best-response functions of the separated firms. When separated, firms may benefit from a strong competitive advantage by setting a below-cost wholesale price (which is then compensated by the fixed fee) which affects downstream quantities and the response of the competitor. Hence, vertical separation is jointly more profitable for the vertical structure, which is a standard result from Bonanno and Vickers (1988). The study of the asymmetric case allows me to show that these effects of integration on technology adoption substantially depends on the vertical structure of the competitor, an effect not highlighted before.

Then, the exploration of the asymmetric market structure allows me to examine the impact of the type of game explored. My work is among the first to fully explore the technology adoption games in an asymmetric set-up. Such games necessitate simulations, but the exploration of such games extend our knowledge on technology adoption patterns. Indeed, the previous literature on technology adoption essentially built up on the assumption of symmetry of the market, which may not fit the reality of many markets. Exploring both preemption and precommitment games in an asymmetric set-up allows me to highlight new intuitions about the solving of these two types of game and their fundamental differences. A first result is that a unique equilibrium may exist under the asymmetric set-up, whereas only multiple symmetric equilibria exist under the symmetric cases. A second result is the fact that for some parameter values, both games yield the same timing of adoption, which is never the case under a symmetric set-up.

Finally, I develop a welfare analysis in which I determine the timing of adoption maximising total surplus. In fact, firms are rarely choosing the socially optimal timings of adoption; the market generally adopts the technology too late according to consumers' preferences, and too early according to the preferences of the adopter's competitor. The balance of such preferences determines whether the *laissez-faire*

adoptions are occurring too late or too early from society's overall perspective. Ultimately, I explore an industrial policy implication of this research: how can the policy-maker influence the adoption timing? Since adoption timing is determined by its profitability, I develop a taxation scheme that influences the timing of adoption without distorting price and quantities.

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), Banerjee and Lin (2003), Buehler and Schmutzler (2008), Chen and Sappington (2010), Faulí-Oller et al. (2011) and Milliou and Pavlou (2013) develop models in which innovation is an extra strategic parameter affected by vertical relations. My work contributes to this literature as it studies the impact of vertical relations on innovative processes.

This paper relates also to the integration literature. This classical branch of Industrial Organisation focuses on the impact of vertical mergers decision both in competitive and innovative terms (e.g. Bonanno and Vickers (1988), Salinger (1988), Hart and Tirole (1990), Ordover et al. (1990), Stefanadis (1997), Riordan (1998), Farrell and Katz (2000), Chen (2001), Brocas (2003), Beladi and Mukherjee (2012), Allain et al. (2014) and Liu (2016)). My paper is a contribution to this literature as it studies the effect of integration in a duopoly set-up in the presence of a cost-reducing technology, in a dynamic framework.

This work is linked to the literature relative to the timing of technology adoption. These articles describe, using game theoretical tools and other economic theories, the determinants of firms' timing choice when adopting a new technology (e.g. Reinganum (1981b), Reinganum (1981a), Fudenberg and Tirole (1985), Quirmbach (1986), Hoppe (2000), Cabral (1990), Riordan (1992), Riordan and Salant (1994), Choi and Thum (1998), Ruiz-Aliseda and Zemsky (2006), Milliou and Petrakis (2011) and Allain et al. (2015)). My work fits in this literature as it exploits the same features as technology adoption models, but I introduce vertical structure and asymmetry issues in such a framework.

Finally, this paper relates to the empirical literature that explored the link between innovative investments and vertical structure in many industries: the coal industry (Lane (1991)); the insurance industry (Forman and Gron (2009)); the auto industry (Helper (1995)); the TV industry (Chipty (2001), D'Annunzio (2017)); and the cement industry (Hortaçsu and Syverson (2007)). My contribution is to explore the adoption timings under several vertical structures and different technology adoption

games, yielding a set of predictions fitting the reality of various industries.

This chapter proceeds as follows. In Section 1.2, the theoretical framework is introduced. I proceed then by backward induction, solving the quantity competition and the contract negotiation first, for every type of vertical structure of the market (Section 1.3). The solving for the timing of adoption under precommitment game is presented in Section 1.4, and the one under the preemption game is presented in Section 1.5. Finally, policy implications are discussed in Section 1.6.

1.2 The Framework

In the following section, the model is described. Much of the notation of this work is taken from Alipranti et al. (2015); our frameworks are very similar, but in this model, the cost-reducing technology is adopted by the upstream firm. While they modeled the relationship between an innovative manufacturer transforming a product from an input provider, this work generalises the reasoning to a simple producer-retailer framework.

1.2.1 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 . This vertical set-up, taken from Bonanno and Vickers (1988), is more tractable than the one with interlocking relationships, and allows us to study a case where there are no foreclosure incentives (nor synergies). The 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 1.1.

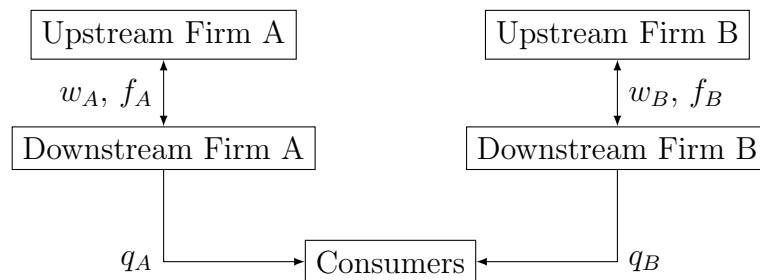


Figure 1.1: The Set-Up

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 rate.²

I make two other standard assumptions. 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. $c - \Delta > 0$), the following assumption must hold:

Assumption 1.1. $M \equiv a - c < \frac{a}{2}$ and $\delta \equiv \frac{\Delta}{M} < \frac{1}{2}$

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

In order to ensure that adoption occurs at a finite time strictly greater than zero and that profit functions are concave,³ the following assumption must hold:

Assumption 1.2. • $(k(t)e^{rt})' < 0$ and $(k(t)e^{rt})'' > 0$

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

1.2.2 The Timing of the Game

The timing of the game is as follows: at Stage 1, upstream firms U_i (firm i when integrated) decide simultaneously their adoption dates T^i . 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 2). Finally, D_A and D_B simultaneously set their quantities (Stage 3). Figure 1.2 represents the timing of this game.

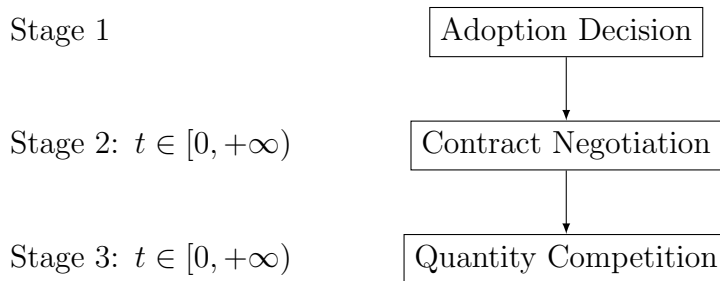


Figure 1.2: The Timing of the Game

²These assumptions are standard in the timing of technology adoption literature, see Reinganum (1981b), Fudenberg and Tirole (1985).

³We want to avoid the situations where adoption occurs immediately or never occurs.

⁴These are also standard assumptions of the technology adoption literature.

Stage 1 depends on the type of adoption game. Under the precommitment game, Stage 1 occurs at time $t = 0$: firms choose their adoption timing and credibly commit to it for the rest of the game. Under the preemption game, Stage 1 occurs at every period $t \geq 0$ until adoption, and firms can react immediately to each other's adoption decision. One way to think of the difference between these two types of game is that information lags are infinite under precommitment whereas they are zero under the preemption game.

The vertical structure of the market is determined exogenously. It can take three forms: the vertically separated case (whereby both firms are vertically separated), the vertically integrated case (whereby both firms are vertically integrated), and the asymmetric case (whereby one firm is integrated and the other is separated).

The focus of this work is not on the vertical merger decision⁵ but on the market performance in terms of technology adoption depending on its vertical structure. The link with integration will be made when comparing the timing of technology adoption between the symmetric cases and the asymmetric case. Such comparison allows me to discuss the impact of integration on adoption timings when the competitor is separated and when the competitor is integrated.

1.3 Quantity Competition and Contract Negotiation

In this section, I solve the last two steps of the game: the quantity competition and the contract negotiation. I do this for the three different vertical structures that can arise: the vertically separated case (Subsection 1.3.1), the vertically integrated case (Subsection 1.3.2) and the asymmetric case (Subsection 1.3.3).

1.3.1 The Vertically Separated Case

In this subsection, the two last stages of the game are solved for the case where both firms are assumed to be vertically separated, as depicted in Figure 1.1. The subscript i (where $i \in \{A, B\}$) is used throughout this subsection as this is a symmetric case: the identity of the firm does not matter.

During the second stage of every period t , D_i chooses q_i to maximise its gross per-period profits π^{D-} :

$$\pi_i^{D-} = (P(Q) - w_i)q_i = (a - q_i - q_j - w_i)q_i \quad (1.1)$$

⁵I explore that dimension of the problem in the next chapter.

where $j \in \{A, B\}$ and $j \neq i$. The subscript of the profits denote the identity of the vertical structure (A or B) and the superscript denotes the position in this vertical structure (U for upstream, D for downstream). The “-” in the superscript denotes gross profits (i.e. without fixed fees). Equilibrium quantity is then:

$$q_i^* = \frac{a - 2w_i + w_j}{3} \quad (1.2)$$

During the first stage of every period t , w_i and f_i (paid from downstream firm to upstream partner) are determined by maximising the Nash bargaining problem:

$$\max_{w_i, f_i} (\pi_i^{U-} + f_i)^\beta (\pi_i^{D-} - f_i)^{(1-\beta)} \quad (1.3)$$

where β is the upstream bargaining power.

Solving for f_i and plugging back into (1.3), one can observe that each upstream firm gets a proportion β of the sum of upstream and downstream gross profits, while the downstream firm gets a proportion $(1 - \beta)$ of same. Therefore, w_i is chosen in order to maximise the sum of the gross profits, and is equal to:

$$w_i^* = \frac{-a + 8c_i - 2c_j}{5} \quad (1.4)$$

Finally, plugging the equilibrium wholesale price into the quantity and profits equation, one gets:

$$\begin{aligned} q_i^* &= \frac{2}{5}(a - 3c_i + 2c_j) \\ \pi_i^{U*} &= \beta(\pi_i^{U-} + \pi_i^{D-}) = \frac{2\beta}{25}(a - 3c_i + 2c_j)^2 \\ \pi_i^{D*} &= (1 - \beta)(\pi_i^{U-} + \pi_i^{D-}) = \frac{2(1 - \beta)}{25}(a - 3c_i + 2c_j)^2 \end{aligned} \quad (1.5)$$

1.3.2 The Vertically Integrated Case

This subsection presents the solving of the case in which both vertical structures are assumed to be vertically integrated. This set-up is represented in Figure 1.3.



Figure 1.3: The Vertically Integrated Case

Hence, firms A and B behave as in a horizontal set-up, without contract negotiation. The per-period profits are then:

$$\pi_i = (P(Q) - c_i)q_i = (a - q_i - q_j - c_i)q_i \quad (1.6)$$

The profits maximising quantity is:

$$q_i^* = \frac{a - 2c_i + c_j}{3} \quad (1.7)$$

Maximised profits are:

$$\pi_i^* = \frac{1}{9}(a - 2c_i + c_j)^2 \quad (1.8)$$

1.3.3 The Asymmetric Case

The case (henceforth “the asymmetric case”) in which one firm is assumed to be vertically integrated and the other one is separated is now investigated. I am going to call firm AI the vertically integrated one, and firm AS the vertically separated one, as represented in Figure 1.4.⁶ Thus, the resolution follows the same steps as Subsection 1.3.1 for firm AS . However, for firm AI , there is no contract negotiation, as in Subsection 1.3.2.

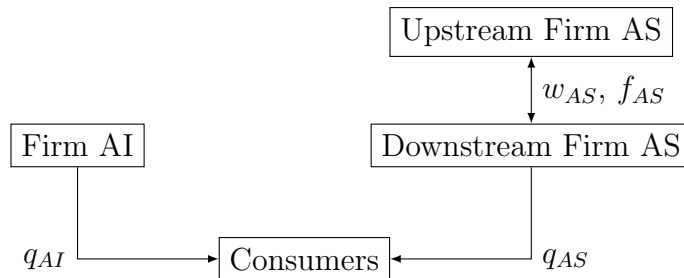


Figure 1.4: The Asymmetric Case

Let's write the downstream per-period profits:

$$\begin{aligned} \pi_{AI} &= (P(Q) - c_{AI})q_{AI} = (a - q_{AI} - q_{AS} - c_{AI})q_{AI} \\ \pi_{AS}^D &= (P(Q) - w_{AS})q_{AS} = (a - q_{AS} - q_{AI} - w_{AS})q_{AS} \end{aligned} \quad (1.9)$$

maximising the previous equations with respect to q_{AI} and q_{AS} yields:

⁶“AI” stands for asymmetrically integrated, and “AS” for asymmetrically separated. Each vertical structure A or B can be AS or AI.

$$\begin{aligned} q_{AI} &= \frac{a - 2c_{AI} + w_{AS}}{3} \\ q_{AS} &= \frac{a - 2w_{AS} + c_{AI}}{3} \end{aligned} \quad (1.10)$$

w_{AS} and f_{AS} are determined by the Nash bargaining problem:

$$\max_{w_{AS}, f_{AS}} (\pi_{AS}^{U-} + f_{AS})^\beta (\pi_{AS}^{D-} - f_{AS})^{(1-\beta)} \quad (1.11)$$

Solving for f_{AS} , then for w_{AS} one gets:

$$\begin{aligned} w_{AS}^* &= \frac{-a - c_{AI} + 6c_{AS}}{4} \\ q_{AS}^* &= \frac{a + c_{AI} - 2c_{AS}}{2} \\ q_{AI}^* &= \frac{a - 3c_{AI} + 2c_{AS}}{4} \end{aligned} \quad (1.12)$$

The optimal profits are then:

$$\begin{aligned} \pi_{AS}^* &= \frac{\beta}{8} (a + c_{AI} - 2c_{AS})^2 \\ \pi_{AI}^* &= \frac{1}{16} (a - 3c_{AI} + 2c_{AS})^2 \end{aligned} \quad (1.13)$$

1.4 The Technology Adoption game under Precomitment

In this section, I solve the first stage of the game under the precommitment game assumptions. As in Reinganum (1981b), only equilibria in pure strategies are considered.⁷ I solve and determine the timing of adoption under the different market set-ups in the three following subsections and I compare them in Subsection 1.4.4.

1.4.1 The Vertically Separated Case

In the following, both firms are assumed to be vertically separated, and the upstream firms are making the adoption decision. Since the situation is symmetric, subscripts denote the technology position (no longer the identity of the vertical structure): the subscript 1 denotes the technology leader (i.e. the first adopter) and the subscript 2 denotes the technology follower (i.e. the second adopter). The technology leader maximises the discounted sum of its infinite stream of per-period profits with respect

⁷Mixed-strategy equilibria are discussed in the next chapter.

to its time of adoption T_1 , and the technology follower maximises its equivalent with respect to T_2 :

$$\begin{aligned} \max_{T_1} \Pi_1^U(T_1, T_2) &= \int_0^{T_1} \pi_0^U e^{-rt} dt + \int_{T_1}^{T_2} \pi_l^U e^{-rt} dt + \int_{T_2}^{\infty} \pi_b^U e^{-rt} dt - k(T_1) \\ \max_{T_2} \Pi_2^U(T_1, T_2) &= \int_0^{T_1} \pi_0^U e^{-rt} dt + \int_{T_1}^{T_2} \pi_f^U e^{-rt} dt + \int_{T_2}^{\infty} \pi_b^U e^{-rt} dt - k(T_2) \end{aligned} \quad (1.14)$$

where $\pi_0^U = \pi_i^{U*}(c, c)$, $\pi_l^U = \pi_i^{U*}(c - \Delta, c)$, $\pi_b^U = \pi_i^{U*}(c - \Delta, c - \Delta)$ and $\pi_f^U = \pi_i^{U*}(c, c - \Delta)$.⁸ Hereinafter, the superscript VS denotes the optimality conditions under the vertically separated case. Denoting:

$$\begin{aligned} I_1^{VS} &\equiv \pi_l^U - \pi_0^U = \frac{6}{25} \beta M^2 \delta (2 + 3\delta) \\ I_2^{VS} &\equiv \pi_b^U - \pi_f^U = \frac{6}{25} \beta M^2 \delta (2 - \delta) \end{aligned} \quad (1.15)$$

First order conditions are:

$$\begin{aligned} I_1^{VS} &= -k'(T_1^{VS}) e^{rT_1^{VS}} \\ I_2^{VS} &= -k'(T_2^{VS}) e^{rT_2^{VS}} \end{aligned} \quad (1.16)$$

From these conditions, one can observe that technology diffusion (i.e. non-simultaneous technology adoption) happens under both pure strategy equilibria. Indeed, since $I_1^{VS} > I_2^{VS}$ and since $-k'(t)e^{rt}$ is decreasing (see proof in Appendix 1.A), $T_1^{VS} < T_2^{VS}$. A first mover advantage is occurring here as first exposed by Reinganum (1981b).⁹

1.4.2 The Vertically Integrated Case

I consider now the case in which both firms are assumed to be integrated, and the integrated firms make the adoption decision. The maximisation problem is the same as in the previous subsection (since the set-up is also symmetric), but now, the integrated firm's per-period payoffs are taken into account.

⁸I write here the per-periods profits $\pi_i(c_i, c_j)$ as a function of the firm's own costs c_i and the other's ones c_j . "0" denotes the situation when no one has adopted, "l" when the firm is the technology leader, "b" when both have adopted and "f" when the firm is the technology follower.

⁹It is easy to show that $\Pi_1^U(T_1^{VS}, T_2^{VS}) > \Pi_1^U(T_2^{VS}, T_2^{VS}) = \Pi_2^U(T_2^{VS}, T_2^{VS}) \geq \Pi_2^U(T_1^{VS}, T_2^{VS})$.

$$\begin{aligned}\max_{T_1} \quad \Pi_1(T_1, T_2) &= \int_0^{T_1} \pi_0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_l e^{-rt} dt + \int_{T_2}^{\infty} \pi_b e^{-rt} dt - k(T_1) \\ \max_{T_2} \quad \Pi_2(T_1, T_2) &= \int_0^{T_1} \pi_0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_f e^{-rt} dt + \int_{T_2}^{\infty} \pi_b e^{-rt} dt - k(T_2)\end{aligned}\quad (1.17)$$

where $\pi_0 = \pi_i^*(c, c)$, $\pi_l = \pi_i^*(c - \Delta, c)$, $\pi_b = \pi_i^*(c - \Delta, c - \Delta)$ and $\pi_f = \pi_i^*(c, c - \Delta)$. The superscript VI denotes the optimality conditions under the vertically integrated case. Denoting:

$$\begin{aligned}I_1^{VI} &\equiv \pi_l - \pi_0 = \frac{4}{9}M^2\delta(1 + \delta) \\ I_2^{VI} &\equiv \pi_b - \pi_f = \frac{4}{9}M^2\end{aligned}\quad (1.18)$$

First order conditions are:

$$\begin{aligned}I_1^{VI} &= -k'(T_1^{VI})e^{rT_1^{VI}} \\ I_2^{VI} &= -k'(T_2^{VI})e^{rT_2^{VI}}\end{aligned}\quad (1.19)$$

Again here, technology diffusion happens under both pure strategy equilibria ($I_1^{VI} > I_2^{VI}$). One can also observe the first mover advantage.¹⁰

1.4.3 The Asymmetric Case

In the asymmetric case, two situations may occur. In pure strategies, either firm AI or firm AS is the technology leader. Hence, I solve the precommitment game under these two possible situations.

Let's consider first the case where firm AI (the vertically integrated firm) is leading. Using the same notations as in the previous sections, firms maximise:

$$\begin{aligned}\max_{T_1} \quad \Pi_{AI}(T_1, T_2) &= \int_0^{T_1} \pi_{AI}^0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_{AI}^l e^{-rt} dt + \int_{T_2}^{\infty} \pi_{AI}^b e^{-rt} dt - k(T_1) \\ \max_{T_2} \quad \Pi_{AS}^U(T_1, T_2) &= \int_0^{T_1} \pi_{AS}^{U_0} e^{-rt} dt + \int_{T_1}^{T_2} \pi_{AS}^{U_f} e^{-rt} dt + \int_{T_2}^{\infty} \pi_{AS}^{U_b} e^{-rt} dt - k(T_2)\end{aligned}\quad (1.20)$$

where $\pi_{AI}^0 = \pi_{AI}^*(c, c)$, $\pi_{AI}^l = \pi_{AI}^*(c - \Delta, c)$, $\pi_{AI}^b = \pi_{AI}^*(c - \Delta, c - \Delta)$, and $\pi_{AS}^{U_0} = \pi_{AS}^{U*}(c, c)$, $\pi_{AS}^{U_f} = \pi_{AS}^{U*}(c, c - \Delta)$, $\pi_{AS}^{U_b} = \pi_{AS}^{U*}(c - \Delta, c - \Delta)$. For the ease of exposition, the optimal conditions are denoted by a subscript indicating the technology position (i.e. 1, 2) and a superscript indicating the identity of the firm (i.e. AI, AS). Denoting:

$$\begin{aligned}I_1^{AI} &\equiv \pi_{AI}^l - \pi_{AI}^0 = \frac{3}{16}M^2\delta(2 + 3\delta) \\ I_2^{AS} &\equiv \pi_{AS}^{U_b} - \pi_{AS}^{U_f} = \frac{1}{2}\beta M^2\delta\end{aligned}\quad (1.21)$$

¹⁰It is easy to show that $\Pi_1(T_1^{VI}, T_2^{VI}) > \Pi_1(T_2^{VI}, T_2^{VI}) = \Pi_2(T_2^{VI}, T_2^{VI}) \geq \Pi_2(T_1^{VI}, T_2^{VI})$.

First order conditions are:

$$\begin{aligned} I_1^{AI} &= -k'(T_1^{AI})e^{rT_1^{AI}} \\ I_2^{AS} &= -k'(T_2^{AS})e^{rT_2^{AS}} \end{aligned} \quad (1.22)$$

This equilibrium exists if and only if $T_1^{AI} < T_2^{AS}$. This occurs for a subset of parameter values:

$$\begin{aligned} &T_1^{AI} < T_2^{AS} \\ \Leftrightarrow &I_1^{AI} > I_2^{AS} \\ \Leftrightarrow &\beta < \beta_1^* \equiv \frac{3}{8}(2 + 3\delta) \end{aligned} \quad (1.23)$$

The case where the vertically separated firm leads is now considered. Using the same notation as before, firms maximise:

$$\begin{aligned} \max_{T_1} \Pi_{AS}^U(T_1, T_2) &= \int_0^{T_1} \pi_{AS}^{U_0} e^{-rt} dt + \int_{T_1}^{T_2} \pi_{AS}^{U_l} e^{-rt} dt + \int_{T_2}^{\infty} \pi_{AS}^{U_b} e^{-rt} dt - k(T_1) \\ \max_{T_2} \Pi_{AI}(T_1, T_2) &= \int_0^{T_1} \pi_{AI}^0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_{AI}^f e^{-rt} dt + \int_{T_2}^{\infty} \pi_{AI}^b e^{-rt} dt - k(T_2) \end{aligned} \quad (1.24)$$

where $\pi_{AS}^{U_0} = \pi_{AS}^{U*}(c, c)$, $\pi_{AS}^{U_l} = \pi_{AS}^{U*}(c - \Delta, c)$, $\pi_{AS}^{U_b} = \pi_{AS}^{U*}(c - \Delta, c - \Delta)$, and $\pi_{AI}^0 = \pi_{AI}^*(c, c)$, $\pi_{AI}^f = \pi_{AI}^*(c, c - \Delta)$, $\pi_{AI}^b = \pi_{AI}^*(c - \Delta, c - \Delta)$.

Denoting:

$$\begin{aligned} I_1^{AS} &\equiv \pi_{AS}^{U_l} - \pi_{AS}^{U_0} = \frac{1}{2}\beta M^2 \delta(1 + \delta) \\ I_2^{AI} &\equiv \pi_{AI}^b - \pi_{AI}^f = \frac{3}{16}M^2 \delta(2 - \delta) \end{aligned} \quad (1.25)$$

First order conditions are:

$$\begin{aligned} I_1^{AS} &= -k'(T_1^{AS})e^{rT_1^{AS}} \\ I_2^{AI} &= -k'(T_2^{AI})e^{rT_2^{AI}} \end{aligned} \quad (1.26)$$

This equilibrium exists if and only if $T_1^{AS} < T_2^{AI}$. This occurs for a subset of parameter values:

$$\begin{aligned} &T_1^{AS} < T_2^{AI} \\ \Leftrightarrow &I_1^{AS} > I_2^{AI} \\ \Leftrightarrow &\beta > \beta_2^* \equiv \frac{3(2 - \delta)}{8(1 + \delta)} \end{aligned} \quad (1.27)$$

Therefore, according to the values of β and δ , several types of equilibria may exist. Figure 1.5 displays the threshold values associated with equilibrium existence

conditions (1.23) and (1.27).

One can state the following proposition.

Proposition 1.1. *In the asymmetric case, the equilibria in pure strategies are as follows:*

1. *when $\beta < \beta_2^*(\delta)$, there is a unique equilibrium in which the vertically integrated firm is the technology leader.*
2. *when $\beta > \beta_1^*(\delta)$, there is a unique equilibrium in which the vertically separated firm is the technology leader.*
3. *when $\beta_2^*(\delta) < \beta < \beta_1^*(\delta)$, there are two pure-strategy equilibria: one in which the vertically integrated firm is the technology leader, one in which the vertically separated firm is the technology leader.*

Proof. This result comes from equations (1.23) and (1.27). □

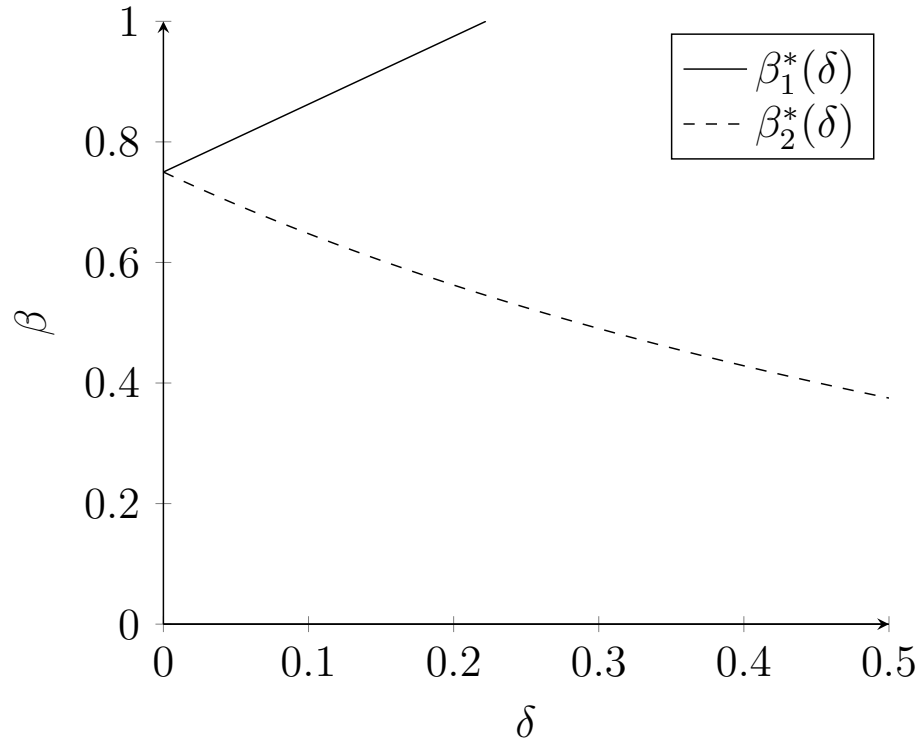


Figure 1.5: Equilibria under Precommitment: the Asymmetric Case

Note: For the values of β and δ below the plain line, the equilibrium in which the vertically integrated firm is the leader exists. For the values of β and δ above the dashed line, the equilibrium in which the vertically separated firm is the leader exists.

Intuitively, the condition of existence of these equilibria relies on the fact that the incentives to adopt first must be higher than those of adopting second. Indeed, from equations (1.26) and (1.22), one can see that decision on timing for the first adopter

depends on the increase in profit from adopting first and, analogously, decision on timing for second adopter depends on the increase in profit from adopting second. For the equilibrium to exist (i.e. for first timing to be earlier than second timing), the first one must be larger than the second one.

When the upstream bargaining power is low (i.e. $\beta < \beta_2^*(\delta)$), the increment to profits of the technology leader (the vertically separated firm) is lower than the one of the technology follower (the vertically integrated firm). In this situation, the upstream firm *AS* faces a hold-up issue; it does not capture much of the benefits from the technology adoption, since the upstream firm's per-period profits are a share β of total profits. While a low upstream bargaining power considerably reduces the incentives to adopt early for the vertically separated firm, the incentives to adopt the technology for the integrated firm are unaffected by it. This is what I call a *bargaining effect*.¹¹ vertical separation implies profit-sharing between upstream and downstream partners, which does not occur under vertical integration.

When the upstream bargaining power is high and the effectiveness of the technology is low (i.e. $\beta > \beta_1^*(\delta)$), the increment to profits of the technology leader (the vertically integrated firm) is lower than the one of the technology follower (the vertically separated firm). This situation occurs due to a mechanism first discussed by Bonanno and Vickers (1988). In a set-up where there are no interlocking relationships and where two-part tariffs are used, vertical separation may be a source of larger profits; an upstream firm can set its wholesale price below cost in order to give a competitive advantage to its downstream partner, and then use the fixed fee to share the total profits. In terms of best response functions, decreasing the wholesale price allows the non-integrated upstream firm to shift the best response curve towards an equilibrium where the quantities and profits of the separated firm are higher than the ones of the integrated competitor. Hence, when β is high, the upstream firm *AS* (which is the technology adopter) captures most of the total profits, and has strong incentives to adopt the technology. Also, when δ is low, the integrated firm *AI* do not strongly benefit from the adoption, while *AS* is not strongly disadvantaged by the technology follower position. Henceforth, the only equilibrium existing for such parameter values is the one where *AS* leads. This is what I call a *strategic effect*.¹² vertical separation gives a competitive advantage through below-cost wholesale pricing.

Finally, the fact that $\beta_1^*(\delta)$ is upward sloping and $\beta_2^*(\delta)$ is downward sloping is due to another feature of the *strategic effect*.¹³ When the effectiveness of the technology

¹¹This effect is equivalent to the “profit-sharing” effect described by Alipranti et al. (2015).

¹²This effect is equivalent to the “terms-of-trade” effect described by Alipranti et al. (2015).

¹³I expose an extended discussion about the impact of δ on the timing of adoption in Appendix

increases, adoption affects not only the equilibrium quantities but also the wholesale price of the separated firm. Indeed, for AS , the wholesale price decreases in reaction to adoption and make the quantities increase even more, which causes an amplification of the gains of being the technology leader. Therefore, $\beta_2^*(\delta)$ is decreasing because I_1^{AS} increases faster with δ than I_2^{AI} . This amplification effect also affects the integrated firm. As a matter of fact, the adoption of the technology by AI increases not only its quantity but also the wholesale price of its competitor, and when the effectiveness of the technology increases, this amplification effect becomes stronger. Therefore, $\beta_1^*(\delta)$ is increasing because I_1^{AI} increases faster with δ than I_2^{AS} . This is an important intuition revealed by the study of the asymmetric case. This complements the work of Alipranti et al. (2015) by highlighting that what matters in a firm's decision to adopt is not only its own vertical structure but also the competitor's vertical structure.

Therefore, the existence of equilibria in the asymmetric case is determined by two effects: a *bargaining* effect and a *strategic* effect. Whenever the *strategic* effect is relatively strong, the equilibrium where AI leads does not exist, and whenever the *bargaining* effect is relatively strong, the equilibrium where AS leads does not exist. In Subsection 1.4.4, I investigate the impact of an exogenous integration on the timing of technology adoption depending on the vertical structure of the competitor.

1.4.4 The Impact of Integration on the Timing of Adoption under Precommitment

In this subsection, I compare the timing of adoption of the new technology under the three different market set-ups previously introduced. The market structure is exogenous. Using the first order conditions of the various aforementioned cases, I obtain a set of threshold values and a ranking of the timing of technology adoption depending on the market structure. This allows discussing further the two main effects of the vertical structure on the timing of adoption, namely, the *strategic* effect and the *bargaining* effect.

1.4.4.1 Impact of Integration when the Competitor is Separated

First, let's compare the vertically separated case and the asymmetric case. Starting from a situation where both firms are separated, firm AS remains separated while firm AI becomes integrated. Therefore, the timing of first and second adoption must be compared for both existing pure strategy equilibria under the asymmetric case,

1.B.

yielding the following four relations:

$$\begin{aligned} T_1^{AI} < T_1^{VS} &\Leftrightarrow 0 \leq \beta < \beta_3^* \equiv \frac{25}{32} \quad \text{and} \quad 0 < \delta \leq 1/2 \\ T_2^{AS} < T_2^{VS} &\Leftrightarrow 0 < \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2 \end{aligned} \quad (1.28)$$

$$\begin{aligned} T_1^{AS} < T_1^{VS} &\Leftrightarrow 0 < \beta \leq 1 \quad \text{and} \quad 0 < \delta < \delta_1^* \equiv \frac{1}{11} \\ T_2^{AI} < T_2^{VS} &\Leftrightarrow 0 \leq \beta < \beta_3^* \equiv \frac{25}{32} \quad \text{and} \quad 0 < \delta \leq 1/2 \end{aligned} \quad (1.29)$$

The range of parameter values for which a certain set-up yields an earlier adoption than another one can then be delimited for both equilibria and both adoptions. In Figure 1.6, the striped area in each case corresponds to the parameter values for which the appropriate equilibrium in the asymmetric case does not exist, and the lines correspond to the threshold values described in equations (1.28) and (1.29). In Figure 1.6(a), for the values of β and δ below the dotted line, integration accelerates first adoption. For all values of β and δ , integration accelerates second adoption. In Figure 1.6(b), for the values of β and δ to the left of the plain line, integration accelerates first adoption. For the values of β and δ below the dotted line, integration accelerates second adoption.

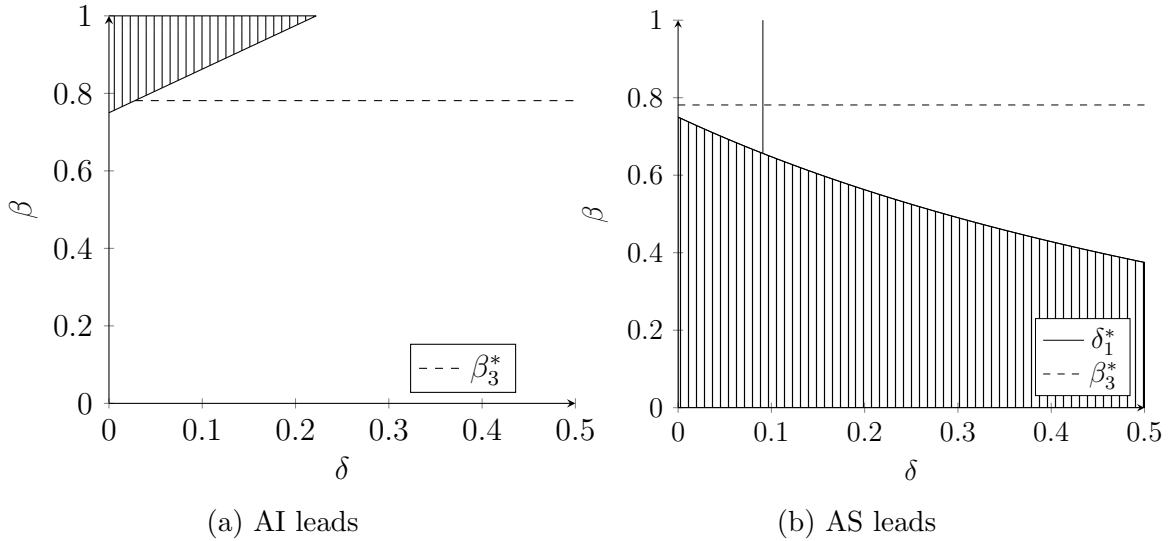


Figure 1.6: Comparison of Precommitment Timing: VS v. Asymmetric Case

Proposition 1.2. *Under the precommitment game, when the competitor is separated and:*

- *when the integrated firm is the technology leader in the asymmetric case, integration always accelerates second adoption and accelerates the first one when $\beta < \beta_3^*$.*

- when the integrated firm is the technology follower in the asymmetric case, integration accelerates first adoption when $\delta < \delta_1^*$ and accelerates the second one when $\beta < \beta_3^*$.

Proof. This result comes from equations (1.28) and (1.29). $\square$

When AI leads, integration necessarily accelerates the second adoption. This is due to the *strategic* effect. Since the benefits from below-cost wholesale pricing are bigger when facing an integrated firm, firm AS adopts the technology faster if the competitor is integrated.

When AI leads, integration accelerates first adoption for all parameter values under the dotted line, which is below $\beta_3^* \approx 0.78$. This is due to the *bargaining* effect: once vertically integrated, the innovator no longer has to share the increment to profits from the innovation. However, when the upstream bargaining power is high, the vertically separated firm gets a higher increment to profits from first adoption than if it was integrated. Then, for $\beta < \beta_3^*$, integration accelerates both adoptions.

For the equilibrium where AS leads, integration makes first adoption occur earlier in the area to the left of the plain line, that is below $\delta_1^* \approx 0.09$. This is due to the same *strategic* effect aforementioned. When the effectiveness of the technology is strong, a separated firm will adopt faster when facing a separated competitor because adoption will affect the wholesale price of this competitor, and it will benefit from the amplification aspect of the *strategic* effect. As δ decreases, this amplification effect vanishes, and when δ is low, the separated firm would adopt the technology faster if its competitor was integrated.

Also, when AS leads, integration accelerates second adoption if and only if $\beta < \beta_3^*$. Here too, the *bargaining* effect is relevant: for low upstream bargaining power values, the increment to profits, and then the incentives to adopt second faster, are higher after integration.

1.4.4.2 Impact of Integration when the Competitor is Integrated

Second, let's compare the asymmetric case to the vertically integrated case: I assume that firm AI is already integrated, and firm AS integrates its downstream partner. Here as well, the two pure strategy equilibria have to be considered, yielding the following set of four equations:

$$\begin{aligned} T_1^{VI} < T_1^{AI} &\Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2 \\ T_2^{VI} < T_2^{AS} &\Leftrightarrow 0 \leq \beta < \beta_4^* \equiv \frac{8}{9} \quad \text{and} \quad 0 < \delta \leq 1/2 \end{aligned} \tag{1.30}$$

$$\begin{aligned}
 T_1^{VI} < T_1^{AS} &\Leftrightarrow 0 \leq \beta < \beta_4^* \equiv \frac{8}{9} \quad \text{and} \quad 0 < \delta \leq 1/2 \\
 T_2^{VI} < T_2^{AI} &\Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2
 \end{aligned}
 \tag{1.31}$$

In Figure 1.7, The stripped area corresponds to the parameter values for which the appropriate equilibrium in the asymmetric case does not exist and the lines corresponds to the threshold values described in equations (1.30) and (1.31). (a) For the values of β and δ below the dotted line, integration accelerates second adoption. For all values of β and δ , integration accelerates first adoption. (b) For the values of β and δ below the dotted line, integration accelerates first adoption. For all values of β and δ , integration accelerates second adoption.

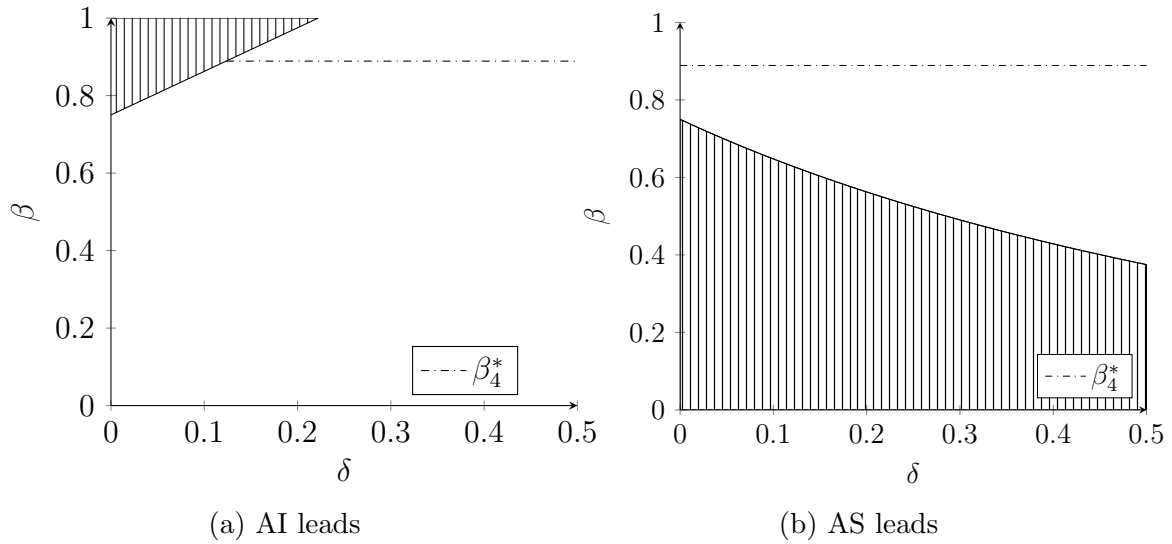


Figure 1.7: Comparison of Precommitment Timing: Asymmetric Case v. VI

Proposition 1.3. *Under the precommitment game, when the competitor is integrated and:*

- *when the integrated firm is the technology leader in the asymmetric case, integration always accelerates first adoption and accelerates the second one when $\beta < \beta_4^*$.*
- *when the integrated firm is the technology follower in the asymmetric case, integration always accelerates second adoption and accelerates the first one when $\beta < \beta_4^*$.*

Proof. This result comes from equations (1.30) and (1.31). $\square$

When AI leads, integration always accelerates first adoption. This is the *strategic* effect: the gain from being the leader are mitigated when the competitor is sepa-

rated and uses below-cost wholesale pricing, and the integration of the competitor alleviates this competitive advantage. When AI leads, integration accelerates second adoption when the upstream bargaining power is below $\beta_4^* \approx 0.89$. This is the *bargaining* effect: when β is low, the innovator (the upstream firm) does not capture much of the gains from adoption when it is separated, and integration in that context increases its incentives to adopt.

When AS leads, integration accelerates the first adoption for $\beta < \beta_4^*$, due to the *bargaining* effect mentioned before. Under this equilibrium, second adoption always occurs earlier after integration; the *strategic* effect previously described prevails.

In sum, the exploration of the asymmetric set-up under the precommitment game highlights two main insights. The first one concerns the resolution of the precommitment game in itself; while the existence of two symmetric pure strategy Nash equilibria is true for all parameter values in the symmetric cases, the precommitment game may have a single pure strategy Nash equilibrium depending on the incentives to adopt of each player. The second insight relates to the effect of integration on the timings of adoption. Such effect depends crucially on the vertical structure of the competitor (i.e. whether it is integrated or not) and on the technology position of the integrating firm. Whenever the *bargaining* effect is strong enough (i.e. when the upstream bargaining power is low), integration unambiguously accelerates adoption. Whenever the *strategic* effect is strong enough (i.e. when β and δ are high), integration may slow down adoption. The next section investigates the preemption game in an asymmetric set-up and allows to discuss whether these insights are specific to the type of game exploited.

1.5 The Technology Adoption game under Preemption

I explore now the impact of the vertical structure on the outcomes of the preemption game as first described by Fudenberg and Tirole (1985). Contrary to the precommitment game where firms commit at $t = 0$ to their adoption timing, firms can adjust their adoption decision at any time in the game. Technically, there is no information lag in the preemption game (while there are infinite ones in the precommitment game): firms immediately know about the other's decisions. Hence, I am using the concept of subgame perfection.

An intuitive way to think about such a game is described by Riordan (1992). One can think of the preemption game as a discrete sequential game where firms take turn in deciding whether to adopt the technology or not, and where the time gap

between every node of the extensive form of the game (i.e. between every step of the sequential game) tends to zero. Time is then continuous, and firms are taking decisions simultaneously, but to solve the game, it is helpful to think of it as a sequential game. In the rest of this section, the superscripts pc and pe denote the precommitment timing and the preemption timing respectively. First, I solve the preemption game in the symmetric set-ups. Second, I solve it in the asymmetric set-up. Finally, I investigate the effect of vertical integration on the timing of adoption.

1.5.1 The Symmetric Cases

The intuition behind the derivation of the adoption timing is better explained with a graph, under the symmetric case. The second adoption occurs at the same timing as in the precommitment game: taking the technology follower position as given, there is no profitable deviation from T_2^{pc} .¹⁴ In Figure 1.8, the payoffs of the technology leader and the technology follower are represented as a function of the first adoption timing, T_1 . The payoff of the technology leader is concave in T_1 , with its maximum at T_1^{pc} , the precommitment timing. The payoff of the technology follower is linearly increasing in T_1 : indeed, the later the first adoption, the shorter the period during which the technology follower suffers from the competitor's exclusive adoption.

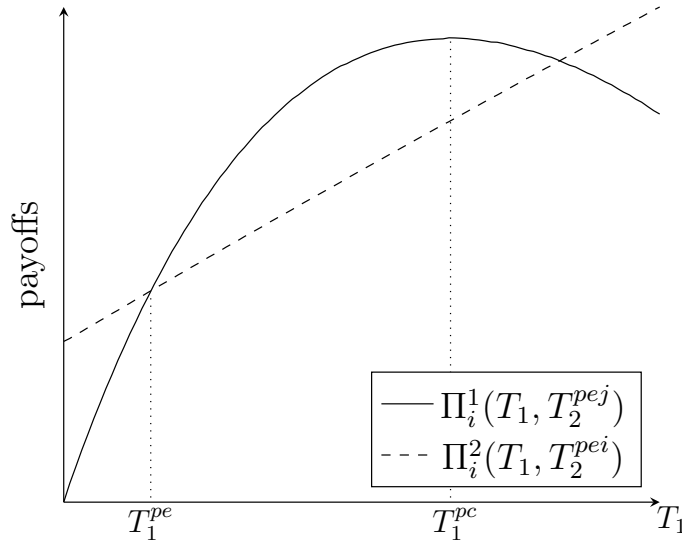


Figure 1.8: Preemption in the Symmetric Case

Note: The plain curve and the dashed line represents respectively the profits of the technology leader and the profits of the technology follower, as a function of the timing of the first adoption. The technology leader's profits reach a maximum at T_1^{pc} , the precommitment timing, and are equal to the follower's ones at T_1^{pe} , the preemption timing.

In the symmetric case, i and j are the same.¹⁵ Hence, per-period payoffs and second adoption timing are the same. Let's assume that a first firm decides to adopt at T_1^{pc} :

¹⁴This is a standard result from the technology adoption literature.

¹⁵The notation i and j is kept for later exposition of the asymmetric case.

one can see that it is a profitable deviation for the follower to adopt at $T_1^{pc} - \epsilon$ for ϵ very small (i.e. $\Pi^2(T_1^{pc}, T_2^{pe}) < \Pi^1(T_1^{pc} - \epsilon, T_2^{pe})$). Knowing this, the first adopter will choose $T_1^{pc} - \epsilon$, but again, adopting at $T_1^{pc} - \epsilon - \epsilon$ is a profitable deviation. This keeps happening until T_1^{pe} , where the payoffs of the technology leader are equal to the ones of the follower, that is when there is no longer any profitable deviation. Hence, rent-equalisation occurs, and there are two subgame perfect equilibria: one where firm i adopts at T_1^{pe} and firm j at T_2^{pe} , and one where j adopts at T_1^{pe} and i at T_2^{pe} .¹⁶

Henceforth, T_1^{pe} is obtained by solving $\Pi^1(T_1, T_2^{pe}) = \Pi^2(T_1, T_2^{pe})$. Such solving yields, in the symmetric set-up, the following condition:

$$\pi^l - \pi^f = r \frac{k(T_1^{pe}) - k(T_2^{pe})}{e^{-rT_1^{pe}} - e^{-rT_2^{pe}}} \quad (1.32)$$

1.5.2 The Asymmetric Case

To our knowledge, no works have explored the outcomes of the preemption game in an asymmetric set-up. Such an exercise has three main difficulties. The first one stems from the fact that pure strategy precommitment equilibria do not exist for all parameter values, which implies that the payoffs as a leader and as a follower may not have the same shape as in Figure 1.8. The second difficulty comes from the fact that T_1^{pe} and T_2^{pe} are not the same for firm i and firm j . The final difficulty is the impossibility of obtaining a closed-form solution for T_1^{pe} , nor even a condition similar to equation (1.32). In the following section, I denote T_1^{pei} the solution¹⁷ to the equation:

$$\Pi_i^1(T_1, T_2^{pej}) = \Pi_i^2(T_1, T_2^{pei}) \quad (1.33)$$

The full description of the different possible situations that may arise during the solving of such a game is described in Appendix 1.C. For the sake of readability, I simply describe the intuitions behind the solving of such a game. I describe first the best response function of the firms in Lemma 1.1.

Lemma 1.1. *Firm i 's adoption decision depends on its willingness to be the technology leader and its capacity to preempt its competitor:*

- *If firm i has an incentive to be the technology leader and:*

¹⁶I am not considering the continuum of equilibria where firms adopt at the same time after T_2 , explored by Fudenberg and Tirole (1985).

¹⁷Actually, I am talking only about the solution before T_1^{pci} , as $\Pi_i^1(T_1, T_2^{pej})$ and $\Pi_i^2(T_1, T_2^{pei})$ intersect twice (see Figure 1.8).

- If $T_1^{pei} < T_1^{pej}$, then firm i adopts first at T_1^{pej} .
- If $T_1^{pci} < T_1^{pej}$, then firm i adopts first at T_1^{pci} .
- If $T_1^{pei} > T_1^{pej}$, then firm i adopts second at T_2^{pei} .
- If firm i has an incentive to be the technology follower, firm i adopts second at T_2^{pei} .

Proof. See Appendix 1.C. □

The intuition behind Lemma 1.1 is as follows. When the firm has some gains from being the technology leader, it may or may not be able to preempt its competitor. In this case, T_1^{pe} measures the capacity to preempt: it represents the earliest timing at which it is profitable to preempt the competitor. If $T_1^{pei} < T_1^{pej}$, it means that Firm j can preempt Firm i up to T_1^{pej} , which is earlier than T_1^{pci} but still later than T_1^{pei} . As one can see from Figure 1.8, Firm i would like to adopt as close as possible to T_1^{pci} , but if it does, it will be preempted by Firm j . Hence, the latest Firm i can adopt without being preempted is T_1^{pej} , the competitor's preemption timing of adoption.¹⁸ If $T_1^{pci} < T_1^{pej}$, this means that Firm j capacity to preempt is so weak that it cannot profitably adopt before the precommitment timing of Firm i . In that case, Firm i adopts at T_1^{pci} . However, as soon as Firm i knows it does not have the capacity to preempt its competitor (i.e. $T_1^{pei} > T_1^{pej}$), it decides to adopt second at T_2^i . A last case that may occur is that Firm i may prefer in all cases to be the technology follower: this may happen whenever its incentives to adopt are extremely low compared to the one of the competitor (this possibility is discussed in Proposition 1.1). In that case, Firm i always chooses to adopt second.

Using the best response function described in Lemma 1.1, the equilibria of the game can be described. I focus on Pareto-dominating equilibria and I choose a classical adoption cost function exploited in several papers (introduced by Fudenberg and Tirole (1985)): $k(t) = e^{-(\alpha+r)t}$, where $\alpha > 0$ is the rate at which the current costs of adoption are falling. Taking an interest rate of 3% ($r = 0.03$), a market capacity equal to one ($M = 1$), and $\alpha = 0.8$, I obtain the set of equilibria depending on the upstream bargaining power and the effectiveness of the technology in Figure 1.9.¹⁹

Proposition 1.4. *There exists a range of parameter values for which the technology adoption equilibria under the preemption game in the asymmetric set-up are as follow:*

¹⁸Technically, Firm i is adopting at $T_1^{pej} - \epsilon$, with ϵ infinitely small, so that j has not incentive to preempt.

¹⁹Market capacity is set to one for simplicity, the interest rate to the reasonable rate of three percent, and the choice of α is guided by the readability of Figure 1.9. Appendix 1.D.1 explores other parameterisations.

- when $\beta < \tilde{\beta}_1$, Firm AI is the technology leader and adopts at the precommitment timing, T_1^{pcAI} .
- when $\tilde{\beta}_1 < \beta < \tilde{\beta}_2$, Firm AI is the technology leader and adopts at the preemption timing of Firm AS, T_1^{peAS} .
- when $\tilde{\beta}_2 < \beta < \tilde{\beta}_3$, Firm AS is the technology leader and adopts at the preemption timing of Firm AI, T_1^{peAI} .
- when $\beta > \tilde{\beta}_3$, Firm AS is the technology leader and adopts at the precommitment timing, T_1^{pcAS} .

Proof. This result comes from simulations using the timing of adoption described in Appendix 1.C. $\square$

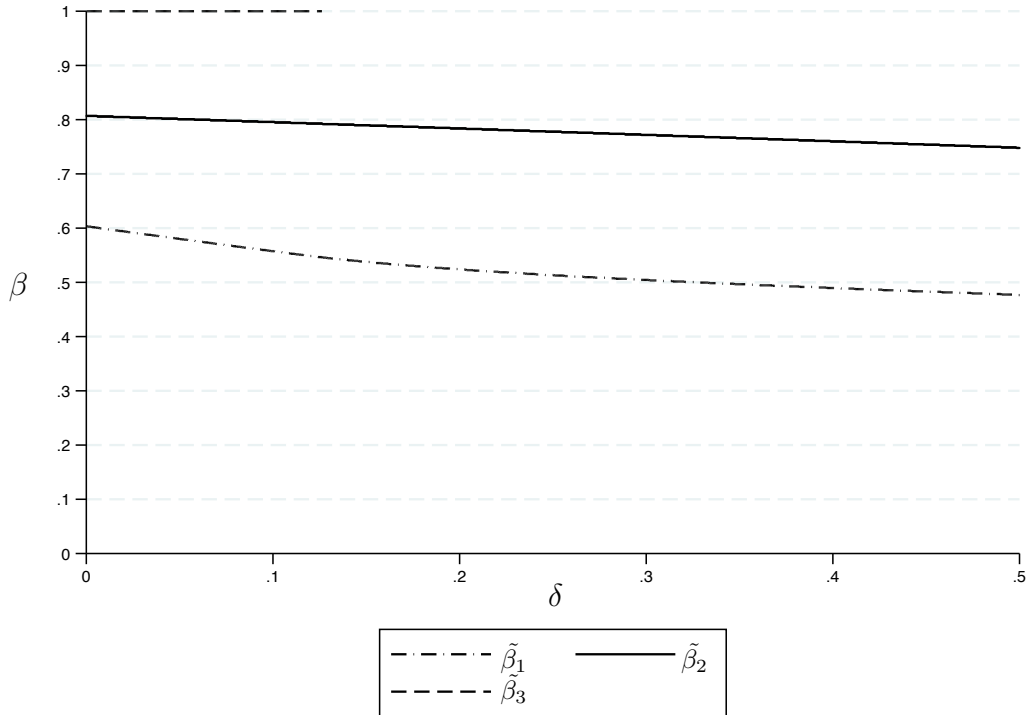


Figure 1.9: Equilibria under Preemption - the Asymmetric Case

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. The three thresholds delimits the four types of equilibria: the one where AI is the technology leader and adopts at the precommitment timing, the one where AI is the technology leader and adopts at the preemption timing, the one where AS is the technology leader and adopts at the preemption timing and the one where AS is the technology leader and adopts at the precommitment timing.

Let's discuss the intuition behind Proposition 1.4. As outlined by Lemma 1.1, a firm's capacity to adopt early is driven by two forces: on the one hand, the firm's capacity to preempt its competitor, and on the other, the competitor's capacity to preempt.

When the upstream bargaining power is low (i.e. $\beta < \tilde{\beta}_3$), the asymmetrically separated firm AS prefers being the technology follower, as it does not have enough incentives to preempt its competitor due to the *bargaining* effect. Within this range of parameters, either firm AS never finds it profitable to adopt first (when β is very low), or its incentives to preempt are so low that firm AI can afford to adopt at its precommitment timing T_1^{pcAI} without fear of being preempted. The opposite situation happens when the upstream bargaining power is very high (i.e. $\beta > \tilde{\beta}_1$). The asymmetrically integrated firm AI prefers being the technology follower, as it does not have enough incentives to preempt its competitor due to the *strategic* effect. Within this range of parameters, the separated firm can adopt at its precommitment timing T_1^{pcAS} .

Hence, a first novel intuition derived the study of the asymmetric case is that the timing of technology adoption described by Fudenberg and Tirole (1985) is not necessarily the timing chosen by firms in a preemption game under an asymmetric set-up. When one firm's incentives to preempt are very low, the outcome of the preemption game is the same than the precommitment game.

When the upstream bargaining power takes intermediate values (i.e. $\tilde{\beta}_3 < \beta < \tilde{\beta}_1$), both firms have incentives to preempt each other which are not too low for one of them to always prefer being the follower. In that case, the firm with the strongest incentives to preempt adopts the technology first and as late as the competitor is able to preempt. In other words, Firm i adopts at T_1^{pej} if $T_1^{pei} \leq T_1^{pej}$. This a second novel intuition derived from the study of the asymmetric case: the less the competitor can preempt, the closer to the precommitment timing (hence the later) the firm will be able to adopt.

A final interesting feature of the asymmetric case is the existence of unique Pareto dominating equilibrium for all parameter values (except $\tilde{\beta}_2$). In the symmetric cases, in the precommitment game as in the preemption game, two symmetric equilibria exist: one where firm A is the leader and one where firm B is the leader. In the asymmetric case, AI is the technology leader for parameter values below $\tilde{\beta}_2$, and AS is the technology leader for those above $\tilde{\beta}_2$. For an upstream bargaining power equal to $\tilde{\beta}_2$, both firms have the same preemption incentives and both equilibria exist.

In sum, the study of the preemption game under an asymmetric set-up highlights how the capacity of the competitor to preempt drives how early adoption will occur.²⁰

²⁰The previous intuitions are qualitatively unaffected by changes in the parameterisation, as shown in Appendix 1.D.

1.5.3 The Impact of Integration on the Timing of Adoption under Preemption

In this subsection, I compare the adoption timing under the two symmetric cases versus the asymmetric case, for the preemption game. The vertical structure of the market is exogenous. The preemption game highlights the same *strategic* and *bargaining* effects, but they are embodied in a single effect that drives the speed of adoption: the *preemption* effect. This effect determines which firm will adopt first and how fast it will adopt in the asymmetric case. The following propositions are derived from simulations; timings are numerically computed using a root-finding algorithm for the parameterisation $M = 1$, $r = 0.03$ and $\alpha = 0.8$, then compared for each $\beta - \delta$ pair.²¹

1.5.3.1 Impact of Integration when the Competitor is Separated

Let's consider the effect of the integration of a firm when the competitor is separated, represented in Figure 1.10.

Proposition 1.5. *There exists a range of parameter values such that, under the preemption game and when the competitor is separated:*

- *integration accelerates first adoption when the integrated firm have strong incentives to adopt first at the precommitment timing in the asymmetric case (i.e. for low values of β).*
- *integration accelerates second adoption when the separated firm is the technology follower in the asymmetric case (i.e. whenever β is not high).*

Proof. This result comes from simulations using the timing of adoption described in Appendix 1.C. □

The impact of integration when the competitor is separated is different though quite similar to the precommitment game. In particular, the effect of integration on the first adoption is driven by what I call the *preemption* effect: a firm will adopt earlier if the preemption threat from competitor is stronger.

For low upstream bargaining power, Firm *AI* knows it cannot be preempted and will adopt at its precommitment timing. However, if it remained separated, it would have adopted at the vertically separated preemption timing, which is late for such low values of β (due to the *bargaining* effect).

²¹The following results are robust changes in the parameterisation, as shown in Appendix 1.D.

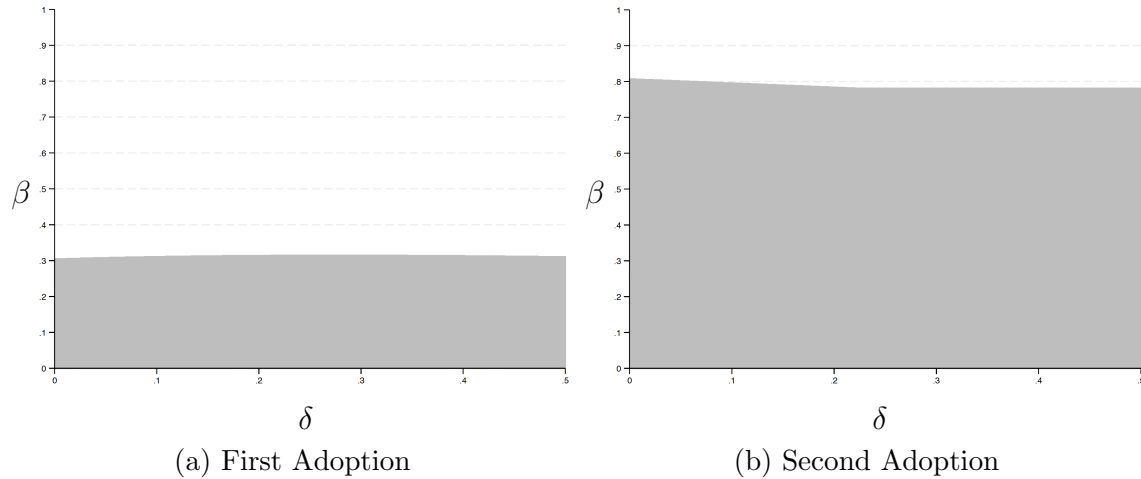


Figure 1.10: Comparison of Preemption Timing: VS v. Asymmetric Case

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. The grey area corresponds to the parameters values for which the adoption is occurring earlier after the integration.

For high upstream bargaining power, the preemption incentive is strong under the vertically separated case due to the *strategic* effect: both firms have strong incentives to adopt when β is high, implying that both firms can preempt each other. In the asymmetric case, for intermediately low values of β , firm AI adopts relatively late due to the poor preemption threat from its competitor. For higher values of β , firm AS adopts first and face relatively poor threat of preemption from its integrated rival (compared to a potential separated one).

Hence, the area of parameters for which integration accelerates first adoption is smaller under the preemption game than under the precommitment game. This is because preemption always occurs under the symmetric set-up, and unless the upstream bargaining power is low, the *preemption* effect drives first adoption faster compared to the asymmetric set-up.

The conclusions for the second adoption are very similar to the precommitment game: as long as the separated firm is the follower in the asymmetric case (i.e. when β is low), the second adoption occurs faster after integration. When β is high, the integrated firm adopts second, but as described in the precommitment case, the *bargaining* effect is relevant: the separated technology follower has incentives to adopt fast.

1.5.3.2 Impact of Integration when the Competitor is Integrated

Let's consider the effect of the integration of a firm when the competitor is integrated. Since the result is unambiguous (i.e. true for all parameter values), I skip the graphical exposition and directly state Proposition 1.6.

Proposition 1.6. *There exists a range of parameter values such that, under the preemption game and when the competitor is integrated, integration always accelerates both adoptions.*

Proof. This result comes from simulations using the timing of adoption described in Appendix 1.C. □

The conclusions about the impact of integration on the timing of adoption is much simpler than under the precommitment game. Integration necessarily accelerates the integration.

For low values of β , *AI* is the technology leader in the asymmetric case. The *strategic* and the *preemption* effect are at stake: an integrated firm has more incentives to adopt when the competitor is integrated, especially because its preemptive threat is stronger.

For high values of β , *AS* is the technology leader in the asymmetric case, and even though the *bargaining* effect is at stake, it is counterbalanced by the *preemption* effect: the poor preemptive threat of *AI* makes *AS* adopt closer to its precommitment timing, which is later than the preemption timing of the vertically integrated case.

Integration always accelerates second adoption when the competitor is already integrated. Indeed, in the precommitment game, the only situation where second adoption occurs faster in the asymmetric case was when β was high, and *AS* was adopting second. In the preemption game, when β is high, *AS* is always the technology leader. Due to the *strategic* effect, the integrated second adopter chooses an earlier adoption date when competing with an integrated firm.

The type of game driving the technology adoption decision significantly affect the impact of the market's vertical structure on the timing of adoption. Especially when the competitor is integrated, the effect of vertical integration on innovative activities strongly differs from the precommitment game to the preemption game.²² The following section explores some welfare analysis.

1.6 Welfare Analysis: the Socially Optimal Timing of Adoption

In this section, I develop some welfare analysis. Do firms adopt at the socially optimal timing? The optimality standard in this section is social welfare; an outcome

²²This result, as shown in Appendix 1.D.2, does not qualitatively depend on the parameterisation.

is optimal if it maximises the sum of profits and consumers' surplus.

First of all, I compute the socially optimal timing of adoption. I maximise the infinite stream of per-period social welfare with respect to timing of adoption. Under the Cournot type of competition I used in this chapter, consumer surplus is simply defined by the squared total output divided by two.²³ Such problem takes the following form:

$$\begin{aligned} \max_{T_1, T_2} SW_i = & \int_0^{T_1} \left(\frac{(q_i^0 + q_j^0)^2}{2} + \pi_i^0 + \pi_j^0 \right) e^{-rt} dt + \int_{T_1}^{T_2} \left(\frac{(q_i^l + q_j^f)^2}{2} + \pi_i^l + \pi_j^f \right) e^{-rt} dt \\ & + \int_{T_2}^{\infty} \left(\frac{(q_i^b + q_j^b)^2}{2} + \pi_i^b + \pi_j^b \right) e^{-rt} dt - k(T_1) - k(T_2) \end{aligned} \quad (1.34)$$

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. Also, in this case, the per-period profits are the total ones (i.e. upstream plus downstream profits). Maximising (1.34) with respect to T_1 and T_2 , I obtain the first order conditions defining the socially optimal timings, per vertical set-up: I_1^{VSsw} , I_2^{VSsw} , I_1^{VISw} , I_2^{VISw} , I_1^{AISw} , I_2^{ASsw} , I_1^{ASsw} and I_2^{AISw} .²⁴

1.6.1 The Socially Optimal Timing under the Precommitment Game

Comparing the socially optimal first order conditions to the *laissez-faire* ones under the precommitment game allows to indicate whether a given adoption is occurring “too fast” or “too late”, depending on the market structure. Under the precommitment game, I obtain the following relationships:

$$\begin{aligned} T_1^{VS} > T_1^{VSsw} & \Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2 \\ T_2^{VS} > T_2^{VSsw} & \Leftrightarrow 0 \leq \beta < \beta_5^* \equiv \frac{2(3-4\delta)}{3(2-\delta)} \quad \text{and} \quad 0 < \delta \leq 1/2 \end{aligned} \quad (1.35)$$

$$\begin{aligned} T_1^{VI} > T_1^{VISw} & \Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2 \\ T_2^{VI} < T_2^{VISw} & \Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2 \end{aligned} \quad (1.36)$$

$$\begin{aligned} T_1^{AI} < T_1^{AISw} & \Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta < \delta_2^* \equiv 2/5 \\ T_2^{AS} > T_2^{ASsw} & \Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2 \end{aligned} \quad (1.37)$$

²³This is a standard Cournot result.

²⁴Notation is the same than before, where the subscript SW is added to indicate social optimality.

$$\begin{aligned}
 T_1^{AS} > T_1^{AS_{sw}} &\Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2 \\
 T_2^{AI} < T_2^{AI_{sw}} &\Leftrightarrow 0 \leq \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2
 \end{aligned}
 \tag{1.38}$$

The threshold values for the vertically separated case and the asymmetric case where AI leads are represented in Figure 1.11.

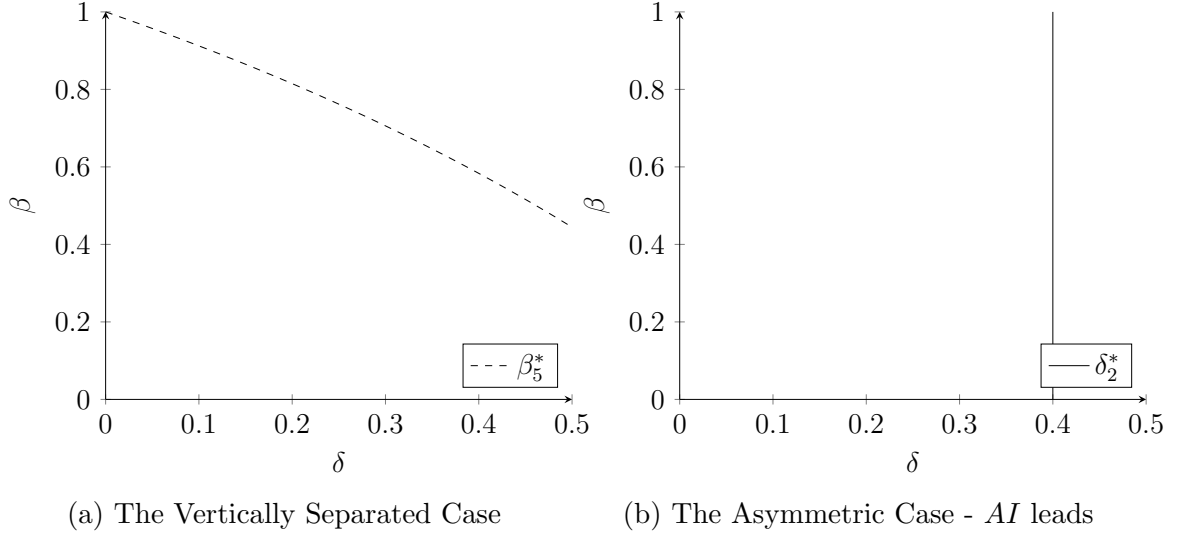


Figure 1.11: The Optimal Timings of Adoption under Precommitment

Note: (a) For the values of β and δ below the dashed curve, second adoption under the vertically separated case occurs too late. (b) For the values of β and δ to the right of the plain line, first adoption occurs too late in the asymmetric case where the integrated firm leads.

Proposition 1.7. *Under the precommitment game, defining optimality as maximizing social welfare, one can state the following:*

- *When both firms are separated, first adoption always occurs too late, and second adoption occurs too late (early) when $\beta < \beta_5^*$ ($\beta > \beta_5^*$).*
- *When both firms are integrated, first adoption always occurs too late, and second adoption always occurs too early.*
- *When the integrated firm leads in the asymmetric case, first adoption occurs too late (early) when $\delta > \delta_2^*$ ($\delta < \delta_2^*$), and second adoption always occurs too late.*
- *When the separated firm leads in the asymmetric case, first adoption always occurs too late, and second adoption always occurs too early.*

Proof. This result comes from equations (1.35) to (1.38) □

The intuition is as follows. In Section 1.4, the timing of adoption depended only on the pay-off of the adopter. Here, the optimal timing of adoption takes into account

three other elements: the pay-off of the downstream firm when the firm is separated, the pay-off of the competitor, and the consumers' surplus. The weight of these different agents in social welfare will determine whether the stand-alone incentives to adopt the technology are too important or not sufficient. In general, the consumers will prefer earlier adoption,²⁵ whereas the competitor will prefer later adoption. Depending on how important these preferences are, the *laissez-faire* adoption may occur too late or too early.

From a policy perspective, which policy instrument could be used in order to incentivize firms to adopt at the right time? The taxation (or subsidisation) schedule should be such that no price or quantity distortion is observed. Ideally, the only variable affected should be the timing of technology adoption. Hence, a lump-sum per-period tax, imposed to the leader from the first adoption on, and another one imposed to the follower from the second adoption on, fits such requirements.²⁶

Hence, the tax Tax_1^i and Tax_2^i are imposed such that the problem of the firms becomes:

$$\begin{aligned} \max_{T_1} \Pi_1^i(T_1, T_2) &= \int_0^{T_1} \pi_i^0 e^{-rt} dt + \int_{T_1}^{T_2} (\pi_i^l - Tax_1^i) e^{-rt} dt + \int_{T_2}^{\infty} (\pi_i^b - Tax_1^i) e^{-rt} dt - k(T_1) \\ \max_{T_2} \Pi_2^i(T_1, T_2) &= \int_0^{T_1} \pi_i^0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_i^f e^{-rt} dt + \int_{T_2}^{\infty} (\pi_i^f - Tax_2^i) e^{-rt} dt - k(T_2) \end{aligned} \quad (1.39)$$

where $i \in \{VS, VI, AI, AS\}$, like before. Solving this maximisation program, it is easy to show that, in order to obtain the socially optimal first order conditions, one should just set:

$$Tax_1^i = I_1^i - I_1^{iSW} \quad Tax_2^i = I_2^i - I_2^{iSW} \quad (1.40)$$

Whenever Tax_1^i and Tax_2^i are negative, they become subsidies: they take positive values when the firms should adopt later, and negative values when they should adopt earlier.

Corollary 1.1. *The market will naturally select the optimal timing of technology adoption if a tax $Tax_1^i = I_1^i - I_1^{iSW}$ is imposed on the technology leader from T_1^i on, and if a tax $Tax_2^i = I_2^i - I_2^{iSW}$ is imposed on the technology follower from T_2^i on.*

Proof. This result comes from Proposition 1.7 and equations (1.39). $\square$

²⁵Indeed, they would like simultaneous immediate adoption, since it triggers the highest output.

²⁶Technically, it is necessary to impose a tax on the technology leader only during the period between the two adoptions. The reason why I still imposed the tax after the second adoption is that, from a social policy point of view, it seems hard to defend a taxation scheme imposed on one firm depending on the actions of its competitor. However, the reader should keep in mind that taxation for the leader does not need to be imposed after second adoption.

Such a taxation schedule does not distort price, quantities or contracts; it solely affects the timing of technology adoption. However, it may also affect the existence of equilibria in the asymmetric case: when AI leads, $T_1^{AISW} < T_2^{ASW}$ only if $\delta > \delta_3^* \equiv 10/31 \approx 0.32$. For parameter values below δ_3^* , the social incentives behind first adoption are lower than the ones behind the second adoption when AI is leading. This is due to the consumers' preference for high quantity, and then for the case where the separated firm, which produces more, has adopted the technology. Therefore, under such taxation schedule, the asymmetric equilibrium where the integrated firm leads does not exist for parameter values below δ_3^* . For values below this threshold, the taxation scheme dissuades the integrated firm to be the leader in the asymmetric case, and the equilibrium where AS is the technology leader is unique.

1.6.2 The Socially Optimal Timing under the Preemption Game

The optimal timing of adoption under the preemption game is the same as under the precommitment game. Also, since the timing of second adoption is the same under both types of game (i.e. $T_2^{pei} = T_2^{pci}$), the conclusions and taxation scheme developed before for the second adoption are also valid under the preemption game.

I run simulations and numerically compare the preemption timings of adoption with the optimal one. Figure 1.12 depicts the parameter values for which first adoption occurs too late. When the optimality conclusions are unambiguous (i.e. true for all parameter values), graphical representation is skipped.

Proposition 1.8. *There exists a range of parameter values such that, under the preemption game and defining optimality as maximising social welfare, one can state the following:*

- *When both firms are separated, first adoption occurs too late (early) for low (high) values of upstream bargaining power .*
- *When both firms are integrated, first adoption always occurs too early.*
- *Under the asymmetric case, first adoption occurs too late when:*
 - *the integrated firm adopts first at the precommitment timing and the effectiveness of the technology is high,*
 - *the separated firm adopts first and the upstream bargaining power is very high.*

Otherwise, first adoption occurs too early.

The conclusions about the optimal timing of second adoption under the precommitment game are also valid under the preemption game.

Proof. This result comes from simulations using the timing of adoption described in Appendix 1.C. $\square$

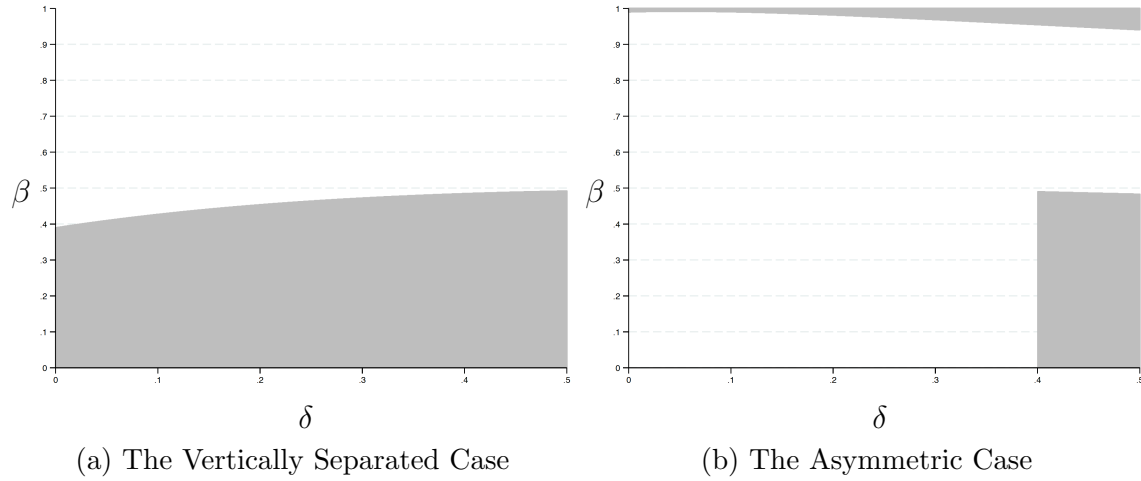


Figure 1.12: The Optimal Timings of Adoption under Preemption

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. The grey areas correspond to the parameters values for which the first adoption is occurring too late according to social welfare criterion. For the parameters values in the blank areas, first adoption is occurring too fast under the preemption game.

The optimality conclusions about first adoption are considerably different. Under the precommitment game, firms were always adopting too late under the vertically integrated case, whereas here, they are always adopting too early. This is due to the *preemption* effect, that forces the leader to adopt much earlier than she would like to, and even the competitor would like it to adopt later.

For the vertically separated case, first adoption was always occurring too late under the precommitment game, whereas it is the case under the preemption game only for low upstream bargaining power. This is related to the *bargaining* effect: when β is low, the preemption incentive is very low, and adoption does not occur fast enough. On the contrary, as soon as β gets bigger, the *preemption* effect gets stronger and adoption occurs too fast according to both firms' taste.

Finally, in the asymmetric case, when the integrated firm leads and adopts at the precommitment timing under the preemption game, it adopts too late for the same parameters range than the precommitment game, that is for high technology effectiveness (i.e. $\delta > \delta_2^*$). When the separated firm leads, it adopts too late only for very high upstream bargaining power values, whereas it was adopting too late for all parameters values under the precommitment game. This is due to the fact that the

preemptive pressure from the competitor is too low when β is high, allowing AS to adopt closer (or at) to its precommitment timing. For the other parameter values, the *preemption* effect is relevant and make the firms adopt earlier than they would like to.²⁷

In terms of taxation policy, it remains the same as in the precommitment one for the second adoption. However, due to the lack of analytical solution, it is impossible to design a general taxation policy for the timing of first adoption under the preemption game. Nevertheless, for the symmetric case, condition (1.32) allows us to figure out which type of taxation would be efficient. It would still consist of a lump-sum tax imposed on the technology leader from its adoption until the next one (in order to affect π^l in the left-hand side of the equation). Indeed, since T_1^{pei} is determined through the equalisation of the leader's rent and the follower's one, imposing such tax (subsidy) would make the first adoption occur later (earlier). Graphically, in Figure 1.8, this would make the leader's profit curve (i.e. the concave one) shift down (or up) towards the follower's profits curve (i.e. the linearly increasing one).²⁸

1.7 Conclusion

Vertical structure is an important driver of economic performance. In particular, it affects the capacity to innovate and to undertake costly research investments. In my model, I show how the vertical structure of a market affect the patterns of adoption of a cost-reducing technology. In particular, I focus on the resolution of the technology adoption game under an asymmetric set-up, whereby one firm is integrated while the other one is separated. The study of the asymmetric case reveals the two main drivers of technology adoption: a *bargaining* and *strategic* effect. The first one relates to the capacity of the adopter to capture the benefits from adoption depending on its vertical structure, whereas the second one relates to the fact that this capacity also depends on the vertical structure of the competitor. These effects can be differentiated thanks to the study of the asymmetric case.

This work improves the understanding of the effect of integration on the technology adoption patterns. The investigation of the asymmetric market structure allows the comparison of the effect of an exogenous vertical integration on technology adoption when the competitor is separated and the situation when the competitor is integrated. Indeed, the impact of integration on the timing of technology adoption dif-

²⁷The previous results are robust to parameterisation changes, as shown in Appendix 1.D.3.

²⁸Concerning the asymmetric case, imposing a taxation and trying to influence the timing of adoption would change the equilibria and the technology positions of the players in the preemption game. Hence, a taxation scheme would distort the price and quantities through the change of the technology positions, which would affect the welfare benefit from such a policy.

fers significantly depending on the competitor's vertical structure. Especially when considering the preemption game, integration unambiguously accelerates adoptions when the competitor is integrated, whereas it is not necessarily the case when it is separated.

Finally, this research develops some policy implications. While it is an important information for competition authorities to know the effect of a vertical integration on innovation, the industrial policy-maker can use a taxation scheme to make the market adopt the technology at the socially optimal time. There are substantial differences between the two types of adoption game on that question. While firms tend to adopt too late under the precommitment game, they tend to adopt too early under the preemption game, due to a *preemption* effect that accelerates adoptions. Also, while a taxation scheme can be easily designed under precommitment and in the symmetric set-ups, it is much harder to impose a taxation system without distorting quantities under preemption and in the asymmetric set-up in general.

In addition, this paper contributes to the technology adoption literature by discussing adoption games in an asymmetric set-up. New features of this type of games is revealed by asymmetry. First, unique pure strategy equilibria may be obtained under the precommitment game, and unique Pareto-dominating equilibria are obtained under the preemption game. Also, the timings of adoption under the preemption game may be identical to the ones of the precommitment game in an asymmetric set-up.

Overall, this work aims to highlight two main features. First, vertical structure is a key driver of the speed of technology adoption, and this must be taken into account when considering the impact of a vertical integration on a market performance. Second, the nature of the technology adoption game considerably affect the predictions of adoption patterns and their welfare impact. These results pave the way to what I think being two important future research. A first one shall investigate empirically which type of game predicts best the adoption patterns within an industry. A second one shall endogenise the integration decision of firms, in order to estimate the impact of innovation on merger decisions on the one hand, and whether such integration should be forbidden or not on the other hand. I explore that research path in my second chapter and show that the presence of cost-reducing technology affects the integration choices of firm, yielding under some conditions the situation of asymmetric integration, whereby one firm chooses to integrate its downstream partner while the competitor remain separated.

Appendix

1.A Proof: $-k'(t)e^{rt}$ is decreasing

In order to prove that $-k'(t)e^{rt}$ is decreasing with t , one must show that:

$$\begin{aligned} & (-k'(t)e^{rt})' < 0 \\ \Leftrightarrow & -(k''(t)e^{rt} + rk'(t)e^{rt}) < 0 \\ \Leftrightarrow & k''(t) + rk'(t) > 0 \end{aligned} \tag{1.41}$$

By Assumption 2.2, $(k(t)e^{rt})' < 0$ and $(k(t)e^{rt})'' > 0$. Therefore:

$$\begin{aligned} & (k(t)e^{rt})' < 0 \\ \Leftrightarrow & k'(t)e^{rt} + rk(t)e^{rt} < 0 \\ \Leftrightarrow & k'(t) + rk(t) < 0 \end{aligned} \tag{1.42}$$

and

$$\begin{aligned} & (k(t)e^{rt})'' > 0 \\ \Leftrightarrow & re^{rt}(k'(t) + rk(t)) + e^{rt}(k''(t) + rk'(t)) > 0 \end{aligned} \tag{1.43}$$

Since the first term of this last equation is negative according to (1.42), then the second term is necessarily positive. In other words, if both (1.42) and (1.43) hold, then (1.41) holds for all t .

1.B Discussion: the Impact of δ on the Timing of Adoption under Precommitment.

This Appendix section discusses the effect of δ , the effectiveness of the technology, on the timings of adoption in the asymmetric case.

The partial derivatives of the first order conditions in the asymmetric case with respect to δ are as follows:

$$\begin{aligned} \frac{\partial I_1^{AI}}{\partial \delta} &= \frac{3}{8}M^2(1+3\delta) & \frac{\partial I_2^{AI}}{\partial \delta} &= \frac{3}{8}M^2(1-\delta) \\ \frac{\partial I_1^{AS}}{\partial \delta} &= \frac{1}{2}M^2\beta(1+2\delta) & \frac{\partial I_2^{AS}}{\partial \delta} &= \frac{1}{2}M^2\beta \end{aligned} \quad (1.44)$$

These derivatives are all positive since $\delta \in [0, 0.5]$ and $\beta \in [0, 1]$. Hence, an increase in technology's effectiveness necessarily accelerates both adoptions.

In order to explain why β_1^* is upward sloping and why β_2^* is downward sloping in Figure 1.5, I define the range of parameter values for which $\frac{\partial I_1^{AI}}{\partial \delta} > \frac{\partial I_2^{AS}}{\partial \delta}$ and $\frac{\partial I_2^{AI}}{\partial \delta} < \frac{\partial I_1^{AS}}{\partial \delta}$, and represent it in Figure 1.B.1.

$$\begin{aligned} \frac{\partial I_1^{AI}}{\partial \delta} > \frac{\partial I_2^{AS}}{\partial \delta} &\Leftrightarrow \beta < \beta'_1 \equiv \frac{3}{4}(1+3\delta) \\ \frac{\partial I_2^{AI}}{\partial \delta} < \frac{\partial I_1^{AS}}{\partial \delta} &\Leftrightarrow \beta > \beta'_2 \equiv \frac{3}{4} \frac{1-\delta}{1+2\delta} \end{aligned} \quad (1.45)$$

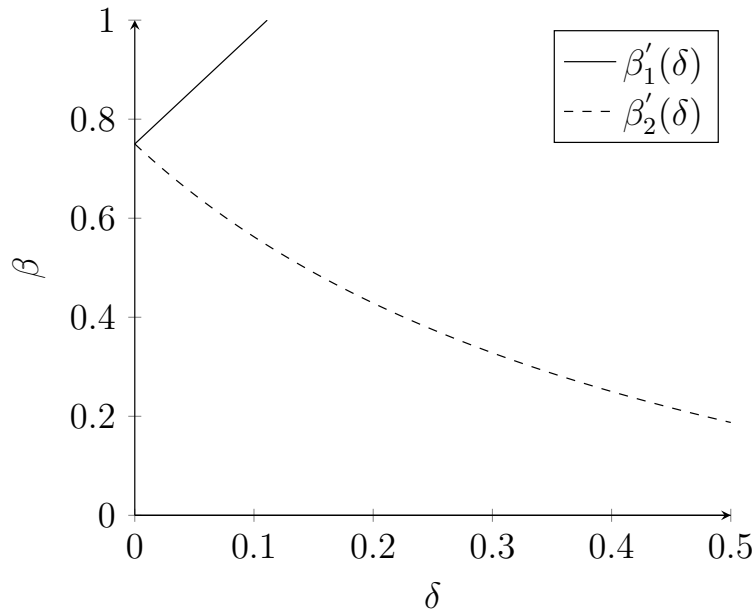


Figure 1.B.1: $\frac{\partial I_1^{AI}}{\partial \delta}$ vs $\frac{\partial I_2^{AS}}{\partial \delta}$, $\frac{\partial I_2^{AI}}{\partial \delta}$ vs $\frac{\partial I_1^{AS}}{\partial \delta}$

Note: For the values of β and δ below the plain line, $\frac{\partial I_1^{AI}}{\partial \delta} > \frac{\partial I_2^{AS}}{\partial \delta}$. For the values of β and δ above the dashed line, $\frac{\partial I_2^{AI}}{\partial \delta} < \frac{\partial I_1^{AS}}{\partial \delta}$.

1.C Solving: Preemption Game under Asymmetry

This appendix presents the solving of the preemption game under the asymmetric set-up. To my knowledge, this type of solving has never been covered by the literature. I explain the solving by presenting graphically the various situations that may occur. The payoffs of the firm when it is the leader and when it is the follower may have different shapes in the asymmetric case, as the payoffs and the timings of adoption of the competitor are not symmetric anymore. Figure 1.C.1 represents the classical case: case 1. I call Firm i the firm I am considering, and Firm j the competitor. The superscripts pc and pe denote the precommitment and the preemption timings respectively.

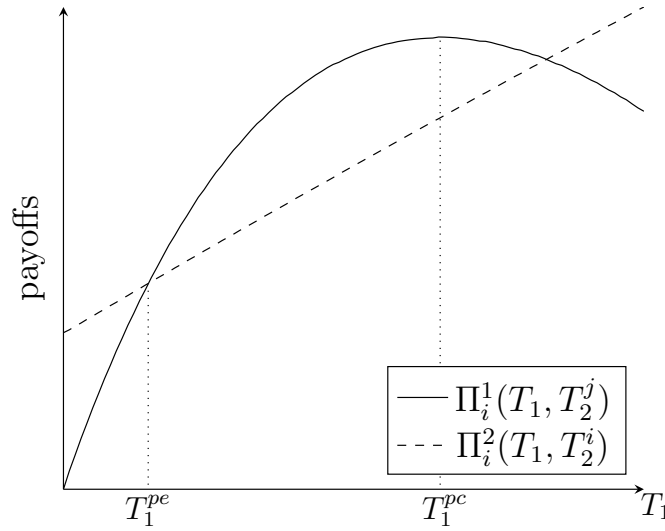


Figure 1.C.1: Preemption in the Asymmetric Case - Case 1

Note: The plain line and the dashed line represents respectively the profits of the technology leader and the profits of the technology follower, as a function of the timing of the first adoption. The technology leader's profits reach a maximum at T_1^{pc} , the precommitment timing, and are equal to the follower's ones at T_1^{pe} , the preemption timing.

In Case 1 (depicted in Figure 1.C.1), several situations may arise, depending on the timings of the competitor. If the competitor have very low incentives to preempt (i.e. $T_1^{pej} > T_1^{pci}$), and cannot even preempt the precommitment timing of Firm i , Firm i will choose its precommitment timing. If the competitor have some incentives to preempt (i.e. $T_1^{pei} < T_1^{pej} < T_1^{pci}$) but Firm i has stronger preemption incentives, Firm i adopts at the preemption timing of Firm j (T_1^{pej}). Indeed, the closest Firm i adopts to T_1^{pci} , the more profitable it is. Hence, it adopts as close as possible to the preemption timing of its competitor. When the competitor has stronger incentives to preempt (i.e. $T_1^{pej} < T_1^{pei}$), Firm i adopts second at T_2^{pci} . Knowing it does not have the possibility to preempt its competitor, Firm i prefers adopting second.

Since the payoffs and the timing of second adoption are not identical for both firms, other cases may arise. Case 0 is represented in Figure 1.C.2. Case 0 and Case 1 are very similar and share the same reasoning. The only difference is that in Case 0, Firm i has such strong incentives to preempt that it can profitably preempt at time $t = 0$. Hence, it cannot be preempted.

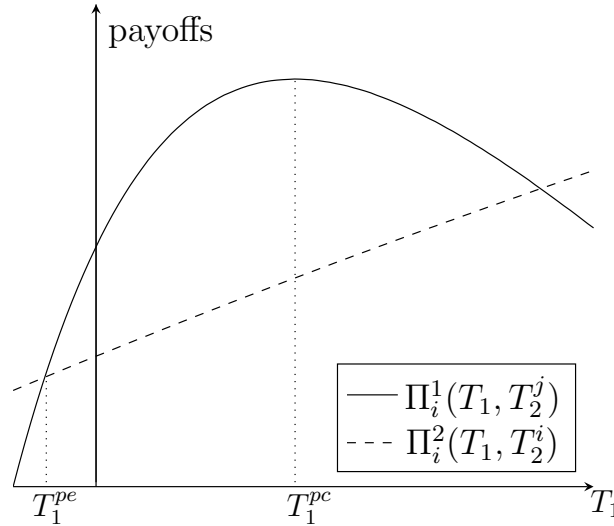


Figure 1.C.2: Preemption in the Asymmetric Case - Case 0

Note: The plain line and the dashed line represents respectively the profits of the technology leader and the profits of the technology follower, as a function of the timing of the first adoption. The technology leader's profits reach a maximum at T_1^{pc} , the precommitment timing, and are equal to the follower's ones at T_1^{pe} , the preemption timing.

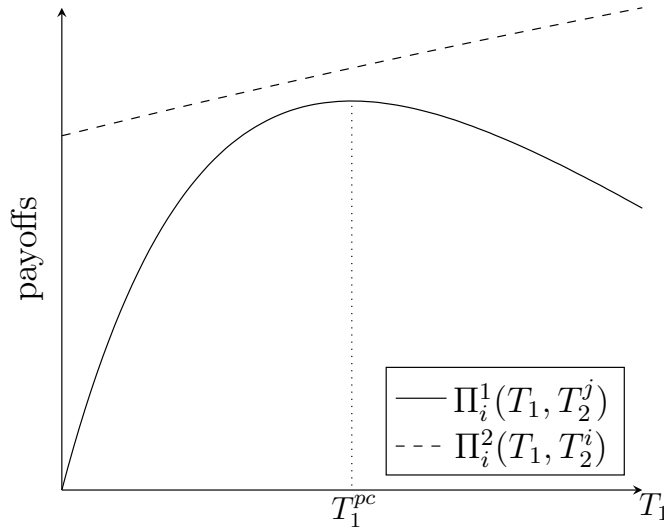


Figure 1.C.3: Preemption in the Asymmetric Case - Case 2

Note: The plain line and the dashed line represents respectively the profits of the technology leader and the profits of the technology follower, as a function of the timing of the first adoption. The technology leader's profits reach a maximum at T_1^{pc} , the precommitment timing. In this specific case, the leader's profits are constantly lower than the follower's ones.

Case 2, depicted in Figure 1.C.3, is a specific case where Firm i has no incentives

to preempt, and always prefer to be the technology follower. This situation arises in areas where the profitability of first adoption is extremely low and the precommitment equilibrium where Firm i leads does not exist. In Case 2, Firm i always adopt second at T_2^{pci} .

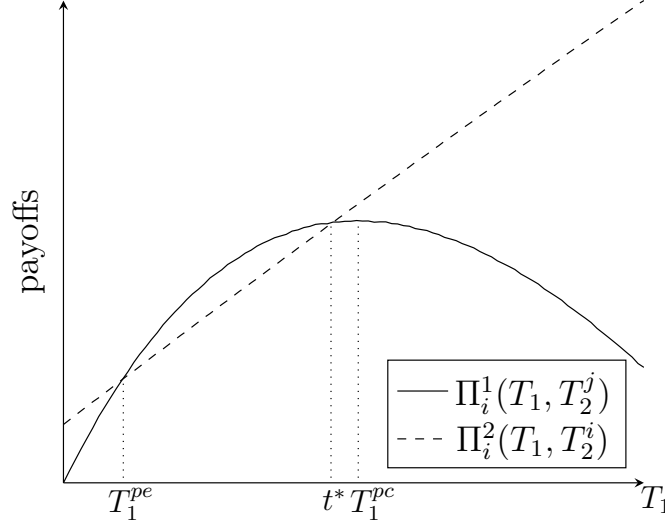


Figure 1.C.4: Preemption Figure in the Asymmetric Case - Case 3

Note: The plain line and the dashed line represents respectively the profits of the technology leader and the profits of the technology follower, as a function of the timing of the first adoption. The technology leader's profits reach a maximum at T_1^{pc} , the precommitment timing, and are equal to the follower's ones at T_1^{pe} , the preemption timing. In this specific case, the leader's profits are lower than the follower's ones at T_1^{pc} .

A final case, Case 3, depicted in Figure 1.C.4, can be thought as an intermediary case between Case 1 and Case 2. The profitability of first adoption is so low that adopting at the precommitment timing brings less profits than adopting second, but for a certain range of timing, preemption is still profitable. t^* is the latest timing for which preemption is profitable. If $T_1^{pcj} > t^*$, Firm i adopts second at T_2^{pci} . Even if it could preempt the competitor, this would bring profits to lower levels than adopting second and let the competitor adopt at its precommitment timing. If $T_1^{pcj} < t^*$, preemption becomes profitable, and Firm i adopts at T_1^{pej} if it can preempt its competitor (i.e. $T_1^{pei} < T_1^{pej}$), or at T_2^{pci} if it cannot (i.e. $T_1^{pei} > T_1^{pej}$).

To solve the game, it is simply sufficient to program the different response functions under the different cases for both Firm AS and AI , and compute the timings of adoption for every parameter combination of β and δ . This is how Figure 1.9 is obtained.

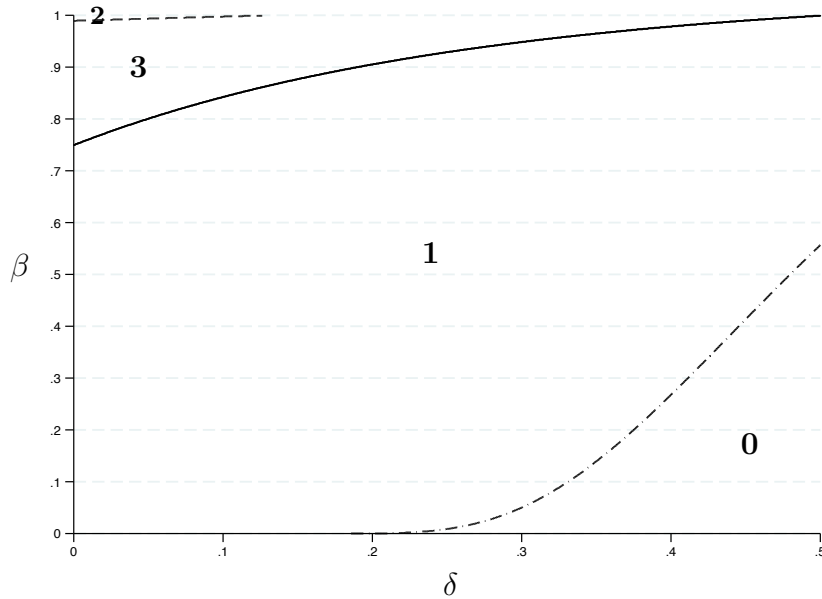
Two problematic situations may occur. The first one would be that both firms would like to adopt second. This situation would occur if both firms were in Case 2. This never happens because it is a situation that arises when the precommitment equilibrium does not exist, and there is always at least one existing equilibrium in

the precommitment game. The second situation that could be problematic would be that both firms want to adopt at time $t = 0$. This corresponds to the case where both firms are in Case 0. This can occur for some parameter values where both firms have strong incentives to adopt, but this happens only if the speed of decrease of the adoption cost is not convex enough (i.e. when α is very low). Hence, I assume α is not too low.²⁹

Table 1.C.1 is a matrix showing the cases faced by both firms and the number of points falling in every combination of case *AS* and case *AI*. I estimated a million combinations of β and δ in total. The following Figures 1.C.5 and 1.C.6 show the different cases faced by Firm *AS* and *AI* depending on the parameter values. Proposition 1.4 is derived from these Figures.

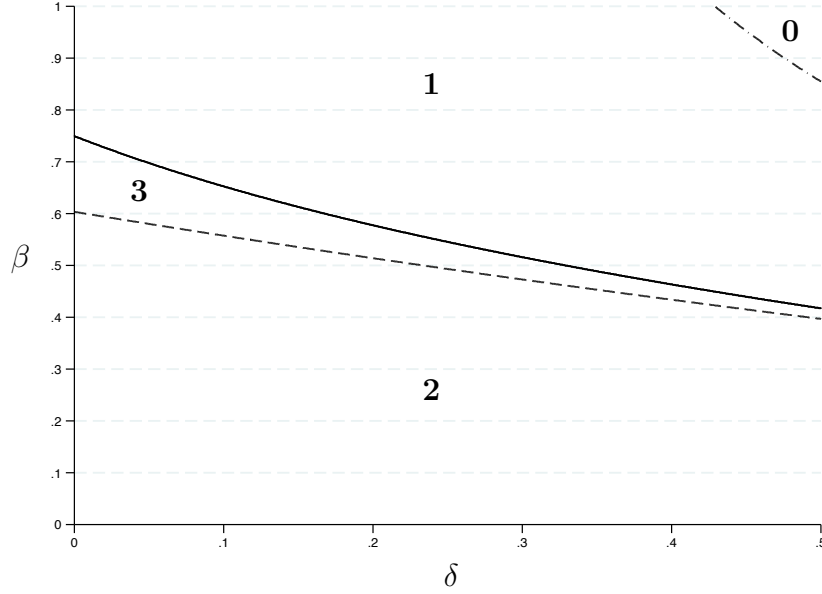
Case AI / Case AS	Case 0	Case 1	Case 2	Case 3
Case 0	0	6,016	107,222	2,042
Case 1	9,904	337,689	388,667	59,844
Case 2	0	1,391	0	0
Case 3	968	86,257	0	0

Table 1.C.1: Cases Matrix - Preemption Game

Figure 1.C.5: Preemption Cases - Firm *AI*

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. The numbers indicate the parameter values for which firm *AI* faces the case 0, 1, 2 or 3.

²⁹The reader can think of this choice as an extra assumption to avoid the situation where firms want to adopt too quickly, similar to the one I made in the precommitment game section.

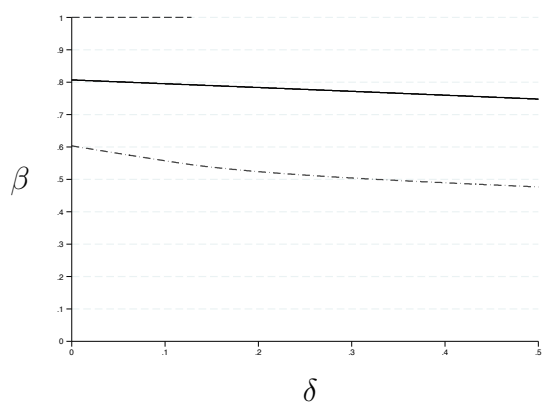
Figure 1.C.6: Preemption Cases - Firm *AS*

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. The numbers indicate the parameter values for which firm *AS* faces the case 0, 1, 2 or 3.

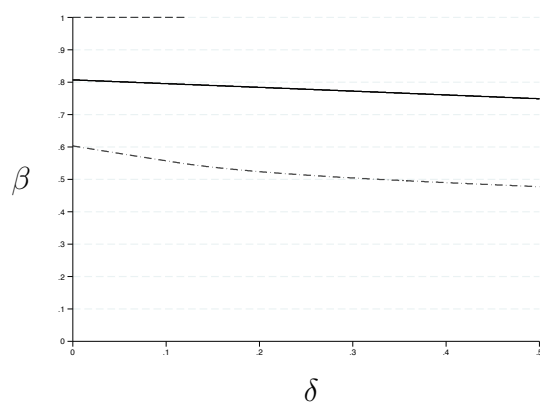
1.D Robustness Check: Alternative Parameterisations

This last appendix section present alternative parameterisations for all the results from the preemption game analysis. Here as well, when the interpretation is unambiguous (i.e. true for all parameter values), graphical exposition is skipped. This is the case for two results: regardless of the parameterisation, integration always accelerates both adoptions when the competitor is integrated, and first adoption always occurs too early in the vertically integrated case.

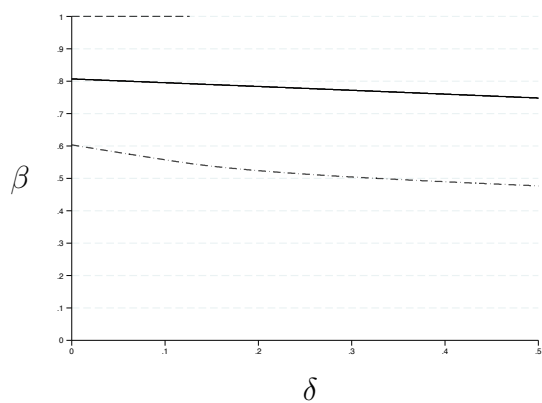
1.D.1 Adoption Equilibria - Preemption Game



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



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

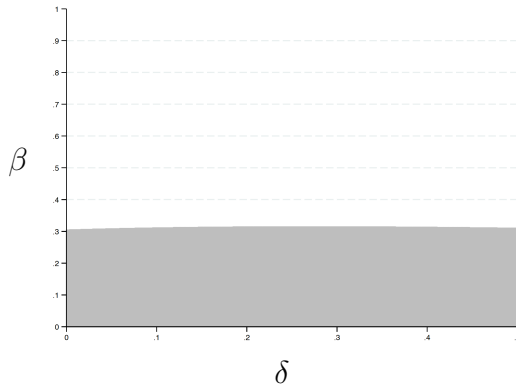


(c) $M = 0.5$, $\alpha = 0.8$ and $r = 0.03$

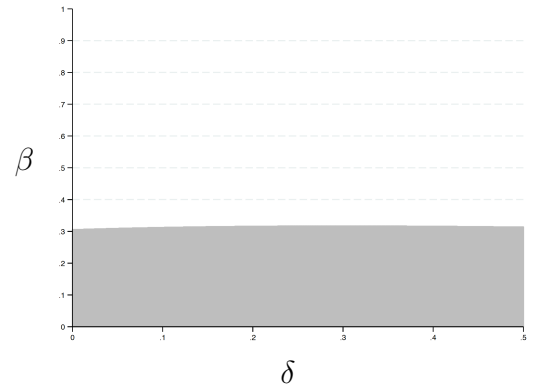
Figure 1.D.1: Comparison of Preemption Timing: First Adoption

Note: These graphs are replications of Figure 1.9 under different parameterisations.

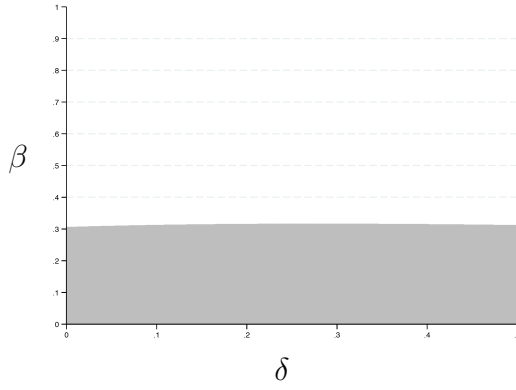
1.D.2 Comparison of Preemption Timing: VS v. Asymmetric Case



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



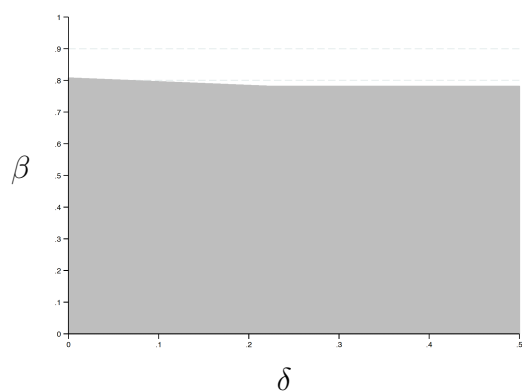
(b) $M = 1$, $\alpha = 0.8$ and $r = 0.05$



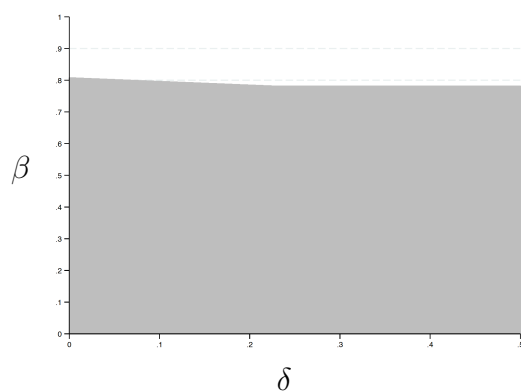
(c) $M = 0.5$, $\alpha = 0.8$ and $r = 0.03$

Figure 1.D.2: Comparison of Preemption Timing: First Adoption

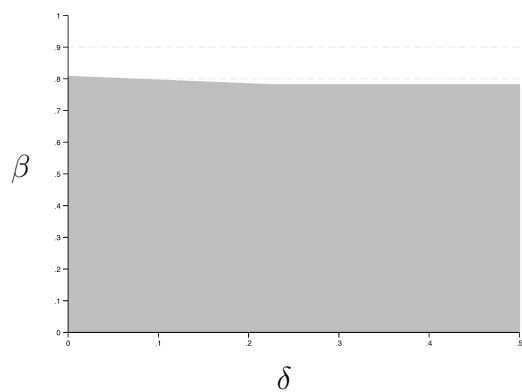
Note: These graphs are replications of Figure 1.10 (a) under different parameterisations.



(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 1.D.3: Comparison of Preemption Timing: Second Adoption
 Note: These graphs are replications of Figure 1.10 (b) under different parameterisations.

1.D.3 The Optimal Timings of First Adoption: The Preemption Game

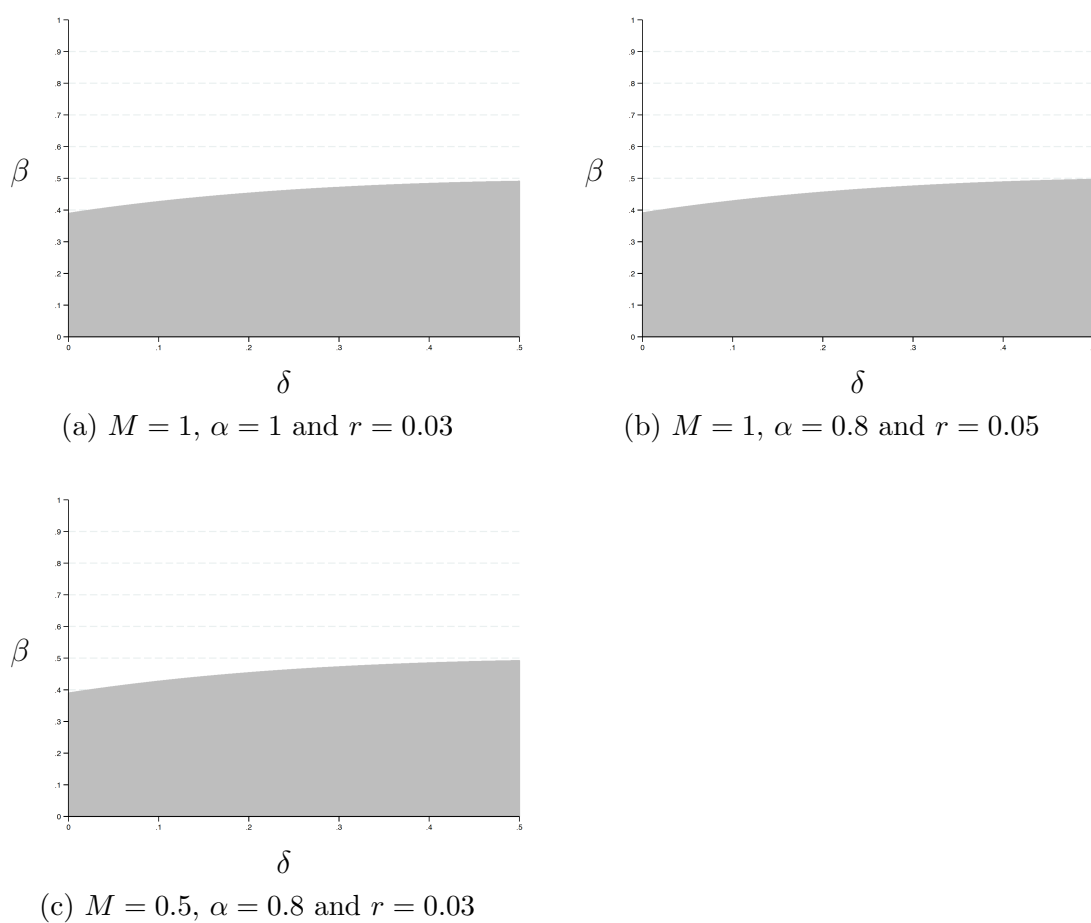
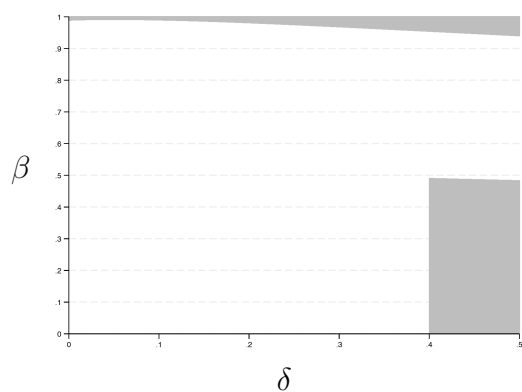
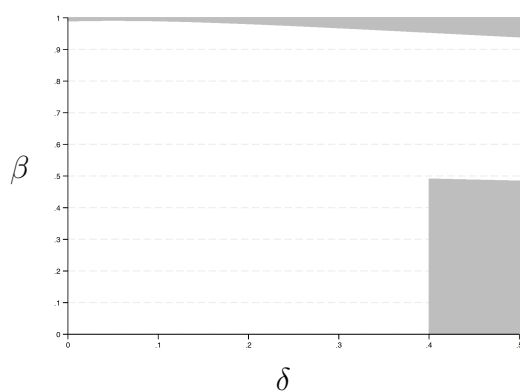


Figure 1.D.4: The Optimal Timings of First Adoption: The Vertically Separated Case

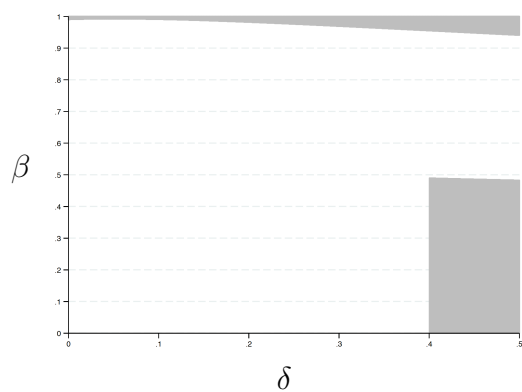
Note: These graphs are replications of Figure 1.12 (a) under different parameterisations.



(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 1.D.5: The Optimal Timings of First Adoption: The Asymmetric Case

Note: These graphs are replications of Figure 1.12 (b) under different parameterisations.

Chapter 2

Vertical Integration in the Presence of a Cost-Reducing Technology

2.1 Introduction

Understanding the motivations behind merger choices is a core concern of competition researchers and policy-makers. Such merger decisions have a crucial impact on consumer welfare, because not only do they affect prices and quantities, they also impact on firms' incentives to innovate and to adopt new technologies. Concerning vertical mergers, the Industrial Organisation literature is not settled in determining whether integration decisions in general serve efficiency or anticompetitive purposes.¹ In this context, there is a need to develop a conceptual framework such that the effect of vertical relations on competition and on innovation are considered jointly. In the industries where technologies are becoming essential assets, it would be inadequate 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 integration and technology adoption decisions.

Two separate vertical chains (i.e. an upstream firm dealing with a downstream firm exclusively) choose whether to integrate or not and the timing 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). This

¹Indeed, the competition authorities' analysis of vertical mergers are still subject to debates. The FTC and the DoJ have just updated their guidelines on vertical mergers (June 30, 2020). Retrieved from <https://www.justice.gov/atr/page/file/1290686/download>

set-up allows me to study integration incentives independently of any synergies or foreclosure mechanisms. When the firm is separated, I assume that the contract between upstream and downstream partner is a two-part tariff determined by a Nash Bargaining process, and that the upstream firm is the technology adopter.

Having a deep understanding of integration mechanisms is becoming particularly challenging because vertical mergers are now occurring in industries that are more and more complex, both in terms of structure and activity. For instance, the technology, media and telecommunication sector (“TMT”) represents a large proportion of the M&A activity around the world (Slade, 2019). The nature of these mergers are often complicated to assess as the definition of the relationships between the merging parties are more and more sophisticated (OECD, 2019). In addition, integrations in the TMT sector considerably affect the development and the adoption of innovative technologies, such as for example optic fibre,² which makes their welfare assessment even more complex.

As such, my two-stage model constructs a link between the vertical integration and the timing of technology adoption literatures, and it is shown that the combination of integration and innovation incentives involves two core mechanisms, extensively discussed in Chapter 1 the *bargaining* effect and the *strategic* effect.

The *bargaining* effect is related to the fact that, when separated, upstream and downstream firms share their joint profits using a fixed fee, and the share that each firm receives depends on its bargaining power. Whenever upstream bargaining power is low, there is a hold-up issue: the upstream firm (the adopter) will delay adoption because it is not getting much profits from it. In this situation, vertical integration solves the hold-up issue and accelerates adoption.

The *strategic* effect is related to the fact that, thanks to two-part tariffs, a separated firm can set its wholesale price below cost in order to give a competitive advantage to its downstream partner and skew market competition in its favour:³ joint profits and outputs are therefore maximised and are higher than the integrated ones. Hence, for high upstream bargaining power, integration slows adoption down.

These two effects drive the second-stage adoption decisions and the first-stage integration decisions, and for some parameter values, asymmetric integration takes place, without the presence of any synergies or foreclosure incentives. I make three specific contributions to the literature.

My first contribution relates to the impact of the presence of a cost-reducing technology on the incentives to integrate. I study an integration game, where both vertical

²KPN/Reggefiber, Case 14.0672.24, ACM Decision of 31/10/2014.

³This is a standard result first shown by Bonanno and Vickers (1988).

chains decide whether to integrate or not depending on the profitability of the operation for the entire structure. In my model, the profitability of the integration is influenced by 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 faster. Such integration's profitability depends on the vertical structure of the competitor (due to the *strategic* effect), and this is how an asymmetric equilibrium in which only one firm integrates can arise. 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. 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 relates to the welfare of integration in the presence of a cost-reducing technology. I evaluate the impact of the integration on consumer surplus and societal welfare. In my model, consumers generally prefer separation (which yields higher output) but may exceptionally prefer integration if adoption is accelerated considerably. In terms of total surplus, the market reaches the optimal outcome for most parameter values.

This work builds upon several literatures. A first relevant literature is the one on vertical relations and their link with innovation: these models take R&D investments as a non-price strategic parameter that influences the competition between vertical chains (e.g. Akgün and Chioveanu (2019), Bakaouka and Milliou (2018), Milliou and Pavlou (2013)).⁴ I contribute to this literature by showing how technology adoption decisions may affect quantity competition, contract negotiations and vertical integration decisions in a duopoly model. Secondly, this paper relates to the integration literature: recent works have shown the influence of R&D investments in vertical structures' decision to integrate (e.g. Reisinger and Tarantino (2019), Loertscher and Riordan (2019), Lin et al. (2019), Liu (2016)).⁵ I contribute to this

⁴Other examples include Stefanadis (1997), Banerjee and Lin (2003), Chen and Sappington (2010), and Faulí-Oller et al. (2011).

⁵Other important papers include Bonanno and Vickers (1988), Salinger (1988), Hart and Tirole

literature by focusing on the timing of technology adoption, and by showing the existence of an asymmetric integration equilibrium in a symmetric set-up. Thirdly, this work is linked to the literature on the timing of technology adoption: these articles investigate the patterns of technology adoption using precommitment and preemption game (e.g. Ruiz-Aliseda (2016), Milliou and Petrakis (2011), Ruiz-Aliseda and Zemsky (2006)).⁶ I contribute to this literature by exploring both types of game in a vertically structured market, in symmetric and asymmetric set-ups. Lastly, this paper relates to the empirical literature that explored the link between innovative investments and vertical structure in many industries, for example: the cement industry (Hortaçsu and Syverson (2007)); the insurance industry (Forman and Gron (2009)); the video game industry (Gil and Warzynski (2014)); and the TV industry (Crawford et al. (2018), D’Annunzio (2017)).

The closest articles 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 by 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. However, my work extends their result to a dynamic framework 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 the welfare analysis.

Finally, this paper is the continuation of Chapter 1. While I investigated the impact of the vertical structure on the timing of adoption under the different adoption games, I endogenise 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 2.2, the set-up of the model and timing of

(1990), Ordover et al. (1990), Riordan (1998), Farrell and Katz (2000), Brocas (2003), and Allain et al. (2014).

⁶Other seminal works include Reinganum (1981b), Reinganum (1981a), Fudenberg and Tirole (1985), Quirmbach (1986), Riordan (1992), Riordan and Salant (1994), and Hoppe (2000).

the game are presented. In Section 2.3, the last three stages of the game are solved. In Section 2.4 and 2.5, the merger game is solved under the precommitment game and the preemption game respectively. Finally, in section 2.6, welfare analysis is discussed.

2.2 The Framework

In the following section, the model is described. The set-up is identical to the one in Chapter 1; 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.

2.2.1 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 .⁷ 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 2.1.

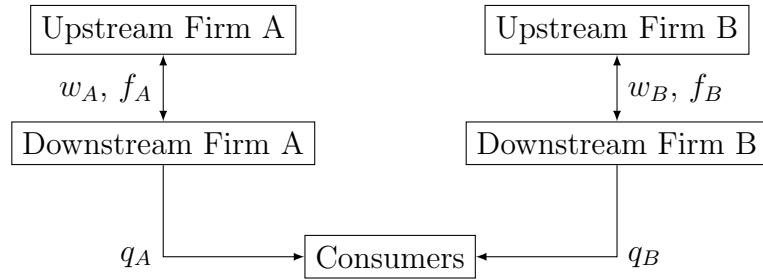


Figure 2.1: The Set-Up

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 rate⁸.

⁷The absence of interlocking relationships allows us to eliminate any foreclosure incentive from the model.

⁸These assumptions are standard in the timing of technology adoption literature.

I make the same two standard assumptions as in Chapter 1, 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 2.1. $M \equiv a - c < \frac{a}{2}$ 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 2.2. • $(k(t)e^{rt})' < 0$ and $(k(t)e^{rt})'' > 0$

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

2.2.2 The Timing of the Game

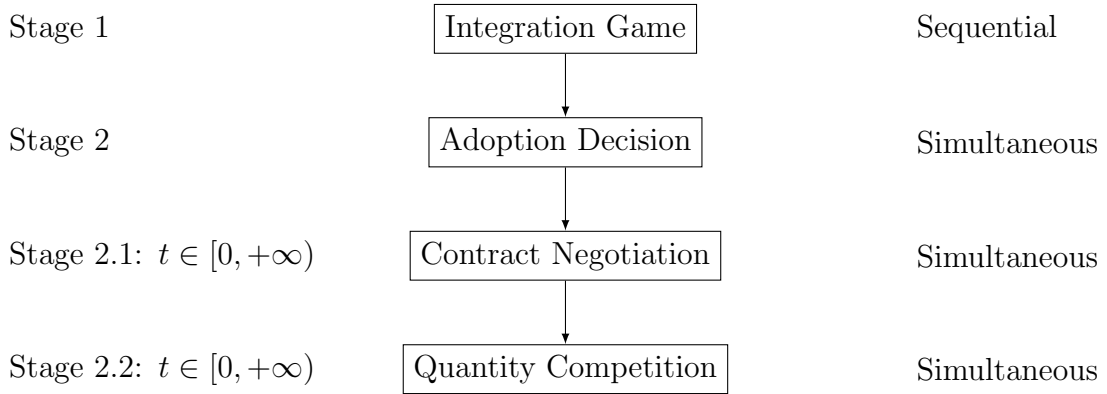


Figure 2.2: The Timing

The timing of the game is represented in Figure 2.2. At Stage 1, the vertical structures, initially separated, decide non-cooperatively and sequentially whether they integrate their downstream partner or not (the integration game assumptions are further discussed in Subsection 2.2.3). Then, at Stage 2, vertical structures (but the upstream firm if separated) decide simultaneously its adoption date T^i . In the pre-commitment game, they commit to such timing at $t = 0$. In the preemption game, Stage 2 occurs at every period $t \geq 0$ until adoption, and firms can react immediately to each other's adoption decision. No other technologies are made available during the rest of the game, and firms cannot change their adoption decision.⁹ 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). I proceed by backward induction, solving the quantity competition, the contract negotiation and the technology adoption game first for every possible type

⁹These are the standard assumptions of the technology adoption literature.

of vertical structure of the market. Once the impact of the vertical structure on the timing of technology adoption is identified, I solve the full game.

In Chapter 1, I solved stages 2, 2.1 and 2.2; and I 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 integration game, under the precommitment game first, under the preemption game then.

2.2.3 The Merger Game in Extensive Form

Let's visualize the merger game using an extensive form, in Figure 2.3. Before choosing the timing of adoption, each vertical chain decides on its vertical structure (i.e. either remaining vertically separated, or becoming vertically integrated). A vertical chain decides to integrate 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; i.e. the game is sequential.¹⁰ *VSA* and *VS* stand for “Vertical Structure A” and “Vertical Structure B” (assuming that, without loss of generality, A makes its decision first). *I* and *NI* stand for “integrate” and “not integrate”. Finally, the payoffs corresponds to the stream of profits.

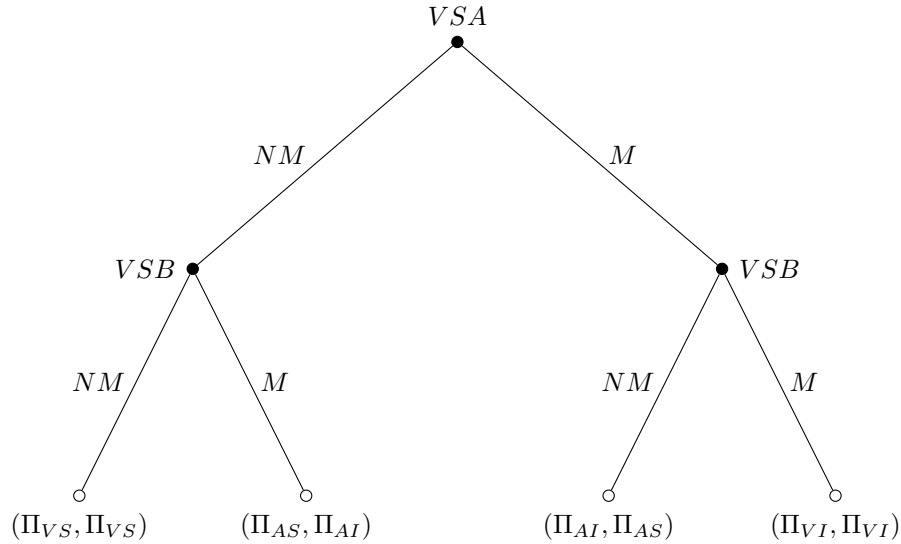


Figure 2.3: The Integration Game

Three different vertical set-ups may arise. The vertically separated case, already represented in Figure 2.1 and denoted *VS*, is the case in which both firms are separated. The vertically integrated case, represented in Figure 2.4 and denoted *VI*, is the case in which both firms are integrated. In that case, there is no contract

¹⁰This assumption is essentially made for tractability purposes.

negotiation stage, and the technology adoption decision is made by the integrated firms.

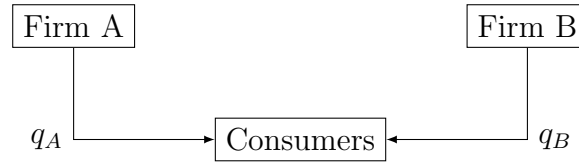


Figure 2.4: The Vertically Integrated Case

The asymmetric case, represented in Figure 2.5, 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).

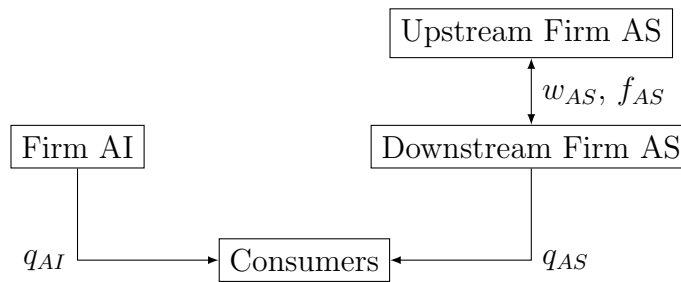


Figure 2.5: The Asymmetric Case

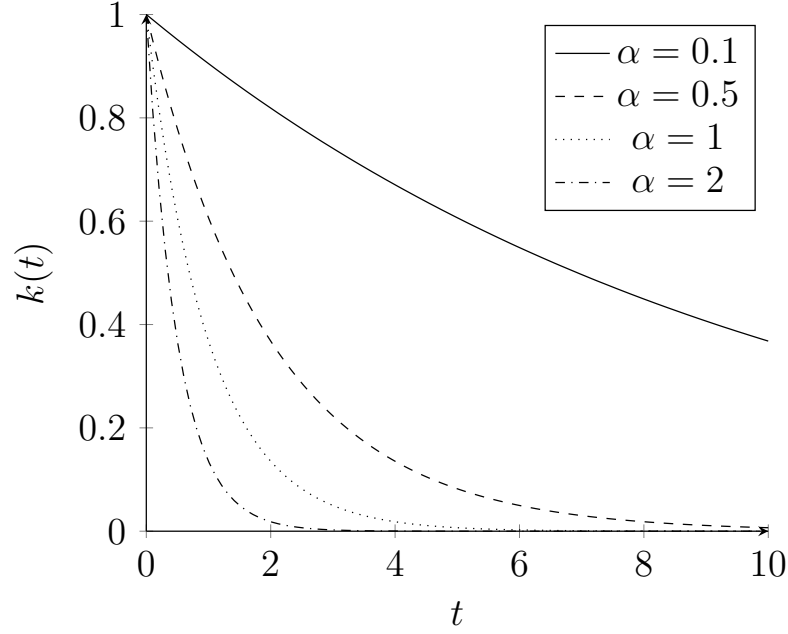
2.2.4 A Specific Adoption Cost Function

In order to solve the integration 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 2.6. One has to set a minimum value for α below which any of these timings could be negative.¹¹

Assumption 2.3. When $k(t) = e^{-(r+\alpha)t}$, $\alpha \geq 0.42M^2$.

¹¹In fact, this is just an extra assumption to fit Assumption 2.2 requirements concerning the adoption cost function.

Figure 2.6: Adoption Costs Function $k(t) = e^{-(r+\alpha)t}$

2.3 Technology Adoption, Contract Negotiation and Quantity Competition

In this section, the last two sub-stages and the second stage of the game are solved: the quantity competition, contract negotiation and adoption decision. These have been extensively discussed in Chapter 1. This is why I cover just the main features of the models and their results (summarized in Table 2.1).

First, I solve the quantity competition. This is a standard Cournot model, and maximising (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 of maximising the Nash bargaining program (equation (2.1)) 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 maximise 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 $(1 - \beta)$.

$$\max_{w_i, f_i} (\pi_i^{U-} + f_i)^\beta (\pi_i^{D-} - f_i)^{(1-\beta)} \quad (2.1)$$

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.

2.3.1 Precommitment Game - Pure-Strategy Equilibria

Under the precommitment game, the firms (upstream if separated) maximise 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 maximises its profits with respect to T_1 and the technology follower maximises its profits with respect to T_2 , as in Equations 2.2.

$$\begin{aligned} \max_{T_1} \Pi_1^i(T_1, T_2) &= \int_0^{T_1} \pi_i^0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_i^l e^{-rt} dt + \int_{T_2}^{\infty} \pi_i^b e^{-rt} dt - k(T_1) \\ \max_{T_2} \Pi_2^j(T_1, T_2) &= \int_0^{T_1} \pi_j^0 e^{-rt} dt + \int_{T_1}^{T_2} \pi_j^f e^{-rt} dt + \int_{T_2}^{\infty} \pi_j^b e^{-rt} dt - k(T_2) \end{aligned} \quad (2.2)$$

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 (2.4). Denoting:

$$\begin{aligned} I_1^i &\equiv \pi_i^l - \pi_i^0 \\ I_2^j &\equiv \pi_j^b - \pi_j^f \end{aligned} \quad (2.3)$$

First order conditions are:

$$\begin{aligned} I_1^i &= -k'(T_1^i) e^{rT_1^i} \\ I_2^j &= -k'(T_2^j) e^{rT_2^j} \end{aligned} \quad (2.4)$$

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 Chapter 1, the precommitment equilibria always exist in the symmetric cases, but do not exist for all parameter values in the asymmetric case.

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 2.1.

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	$w_i^{VS} = \frac{-a + 8c_i - 2c_j}{5}$	n.a.	$w_{AS} = \frac{-a - c_{AI} + 6c_{AS}}{4}$
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 2.1: Summary - Equilibrium values

2.3.2 Preemption Game

Under the preemption game, the timing of second adoption is identical to the one of the precommitment game.¹² 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-equalisation" result from Fudenberg and Tirole (1985). Using the concept of

¹²This is a standard result from the preemption game literature.

subgame perfection, I solve the preemption game in Chapter 1 using simulations under the different vertical structures.

2.3.3 Precommitment Game - Mixed-Strategy Equilibrium

Finally, it is important to note that the precommitment game has also a mixed-strategy equilibrium. Such a strategy consists in associating a probability p with the equilibrium timing T_1 and a probability $(1 - p)$ with T_2 . In Chapter 1, I focused on the timing of adoption in pure-strategy, but I will use the mixed-strategy equilibrium to solve the integration game in section 2.4.

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.¹³ Hence, firms randomize only between T_1 and T_2 , and the game can be represented in a normal form.

		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 2.2: The Precommitment Game: Normal Form.

In Table 2.2, 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 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 2.2 and equation (2.5). Solving for p_A and p_B , respectively the probability of playing T_1^A and T_1^B :

$$p_A = \frac{\Pi_B^1 - \Pi_B^{22}}{\Pi_B^1 - \Pi_B^{22} + \Pi_B^2 - \Pi_B^{11}} \quad p_B = \frac{\Pi_A^1 - \Pi_A^{22}}{\Pi_A^1 - \Pi_A^{22} + \Pi_A^2 - \Pi_A^{11}} \quad (2.5)$$

In the symmetric cases, these probabilities are equal, whereas in the asymmetric case, they are not.

¹³This is due to the fact that firms commit to their timing of adoption at $t = 0$.

2.4 Integration Decision under Precommitment Game

In this section, the first stage of the full game is solved under the precommitment game. Using the timing of adoption, the quantities and the per-period profits previously derived, I compare the profitability of the different vertical set-ups in order to solve the overall game.

When solving the integration game (stage 1) using the pure-strategy equilibria of the adoption game (stage 2), I face an issue of equilibrium selection. The problem is the following one: as one can see in Figure 2.3, solving the game involves computing the profitability of integration when the competitor is separated and when the competitor is integrated. In particular, for the first integration, I 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 vertical structure (hence, $\Pi_{VS} \equiv \Pi_{VS}^U + \Pi_{VS}^D$ and $\Pi_{AS} \equiv \Pi_{AS}^U + \Pi_{AS}^D$ in Figure 2.3). 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, two symmetric Nash equilibria in pure strategies arise for every set-up, and no standard selection criterion helps in selecting one.

As described in Appendix 2.A, I focus on the mixed-strategy equilibrium of the simultaneous adoption game (stage 2) and use the firms' expected profits to solve the sequential integration game (stage 1). In particular, I 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 $\Pi_{AS} - \Pi_{VI} \geq 0$ with respect to β and δ , taking M , r and α as given. However, such equations do not have a closed-form solutions. Therefore, I run simulations. In the following figures, I parametrize $M = 1$, $r = 0.03$ and $\alpha = 0.8$.¹⁴ In Appendix 2.C, I explore other parameterisations and show that they do not affect my results qualitatively.

Let's solve the game backwards using Figure 2.3. The second player may face two situations: either the first player didn't merge (left node) or it did merge (right 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 define the first player's decision according to the sign of these equations.

¹⁴The 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 match the parameterisation of Chapter 1.

If $\Pi_{AI} - \Pi_{VS} > 0$ and $\Pi_{AS} - \Pi_{VI} < 0$, 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 unique subgame perfect equilibrium.

If $\Pi_{AI} - \Pi_{VS} < 0$ and $\Pi_{AS} - \Pi_{VI} > 0$, the second firm never merges, and the firm's decision depends on $\Pi_{AI} - \Pi_{VS}$, 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 $\Pi_{AS} - \Pi_{VI} < 0$, 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} . For this parameterisation, the vertically integrated case is always preferable (compared with the vertically separated case), so that it is the unique subgame perfect equilibrium. 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.

If $\Pi_{AI} - \Pi_{VS} > 0$ and $\Pi_{AS} - \Pi_{VI} > 0$, 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. For this parameterisation, 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 2.7.¹⁵ For parameter values in the area 0, no integration occurs. For parameter values in area 2, both firms integrate. In area 1, only one integration occurs.

Proposition 2.1. *Under the precommitment game, there exists a range of parameter values for which 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 .*

Proof. This result comes from simulations using the timing of adoption described in Chapter 1 and the expected profit functions described in Appendix 2.A. $\square$

The profitability of integration is driven by two features: the effect of integration on per-period profits and the effect of integration on the timing of technology adoption.

¹⁵The results are represented using specific parameter values, which are $M = 1$, $\alpha = 0.8$ and $r = 0.03$. In Appendix 2.C, I show that the parameterisation does not have a qualitative impact on my results, by making reproductions of Figure 2.7 with higher α , lower M and higher r respectively.

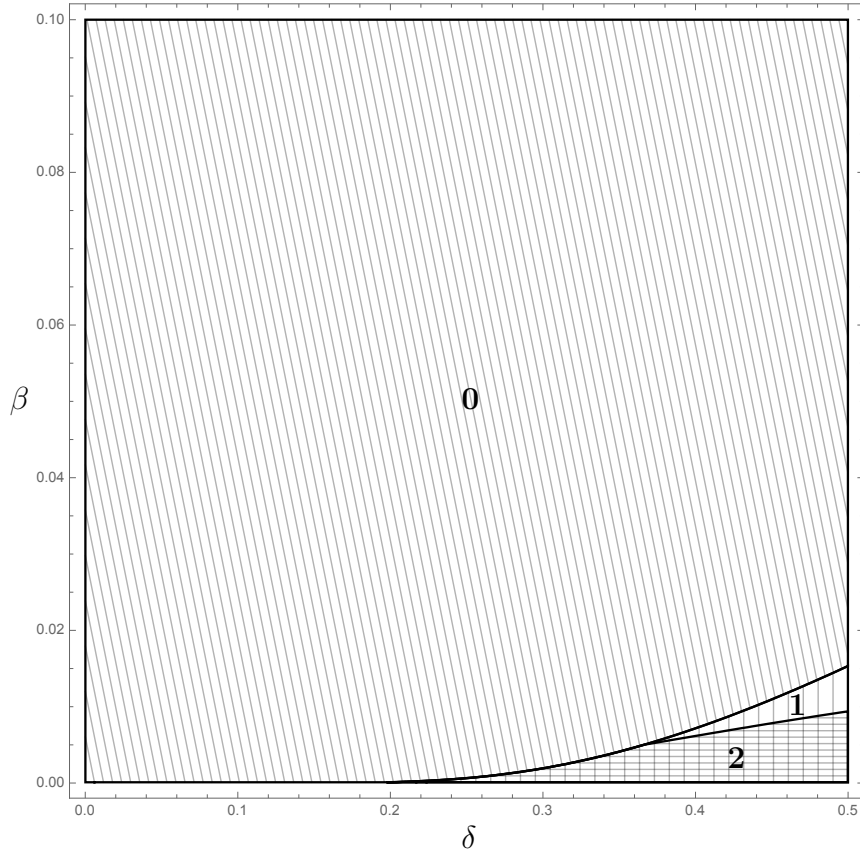


Figure 2.7: Number of Integrations under Precommitment

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. This graph is restricted to values of β below 0.1 for readability, as the rest of graph (from 0.1 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.

The influence of per-period profits on the profitability of integration is twofold. On the one hand, vertical separation yields higher total per-period profits. Indeed, one can see from Table 2.1 that $\pi_{VS} > \pi_{AI}$ and $\pi_{AS} > \pi_{VI}$ (for equal costs). This is due to the *strategic* effect, which enables the separated firm to maximise its total profits using below-cost wholesale pricing. This is the main reason why vertical separation is the equilibrium of the game for most values of β and δ . On the other hand, when upstream bargaining power is low, there is a unique pure strategy equilibrium of the precommitment game in the asymmetric case: Firm AI is necessarily the technology leader and Firm AS is necessarily the technology follower. In the symmetric cases, there is uncertainty about the technology position.¹⁶ This difference is an incentive to integrate when β is low. When the competitor is separated, integrating the downstream partner allows to gain the technology leader position for certain. When the competitor is integrated, the firm will be the technology follower for certain if it doesn't integrate its downstream partner.

¹⁶As explained in Appendix 2.A, firms randomize between T_1 and T_2 in the symmetric cases

The impact of the timing of technology adoption on the profitability of integration is also twofold. On the one hand, timing of adoption affects the total profits through the adoption costs. If integration accelerates adoption, then it increases adoption costs. For low upstream bargaining power, it is always the case. On the other hand, integration may affect 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 of time. Indeed, from the first order conditions described in Table 2.1, one can show that for low upstream bargaining power, the time span between adoptions is bigger under the asymmetric case.¹⁷ This also explains why integration when the competitor is already integrated is profitable: in the asymmetric case, the separated firm suffers from the technology follower position for a longer period of time.

Consequently, for this parameterisation, the asymmetric case occurs for an intermediate 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 high. The existence of this asymmetric equilibrium stems from the *strategic* effect: the incentives to integrate are slightly different when the competitor is integrated compared to when it is separated.

Hence, starting from a purely symmetric situation, the presence of a new cost-reducing technology can make an asymmetric equilibrium arise. This is not due to foreclosure incentives or any synergies, 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. However, the mechanism that lead to such a result is very different in their work: asymmetric integration arises when market capacity is not large enough to cover the integration-related fixed costs of both firms, whereas in this paper, asymmetric integration arises because the effect of integration on the speed of technology adoption depends on the vertical structure of the competitor. In addition, 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 competition relevant: the bargaining power of vertical partners and the efficiency of a technology are metrics particularly exploitable by competition authorities. In sum, our works demonstrate a consistent theory using different models.

¹⁷The impact of integration on the time span between adoptions is described in Appendix 2.B.

2.5 Integration 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-equalisation 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.

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 use simulations, in which, for a given parameterisation, 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).¹⁸ For each of these million points, I compute and compare the profit values and plot the range of parameter values for which integration is profitable. I use the same parameterisation than Chapter 1 ($M = 1$, $r = 0.03$ and $\alpha = 0.8$). However, I run alternative parameterisations in Appendix 2.C, 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 solution to the preemption game under an asymmetric set-up is less straightforward. Chapter 1 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 Pareto-dominating equilibrium. Hence, there is no issue of equilibrium selection in that case, and in the vertically integrated case, 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-equalisation occurs, but only at the upstream level. Therefore, when comparing the profits of the entire vertical structure (i.e. upstream plus downstream), it differs con-

¹⁸For 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.

siderably 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.¹⁹

Keeping in mind this difficulty, I 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 am able to solve the game conditional on whether the symmetrically vertically separated firm anticipates being the technology leader or not. This approach allows me to develop further intuitions and mechanisms concerning the merging incentives under technology adoption.

2.5.1 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 2.4: 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} .²⁰

As represented in Figure 2.8, under the assumption that the firm will experience the follower's profits when separated, Proposition 2.1 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 Chapter 1, 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, even in the scenario in which precommitment occur, the profits of the

¹⁹I 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.

²⁰The observations previously made still hold (i.e. $\Pi_{VS} < \Pi_{VI}$ for all parameters). The following results holds for $M = 1$, $r = 0.03$ and $\alpha = 0.8$, but are robust to parameterisation changes, as shown in Appendix 2.C.

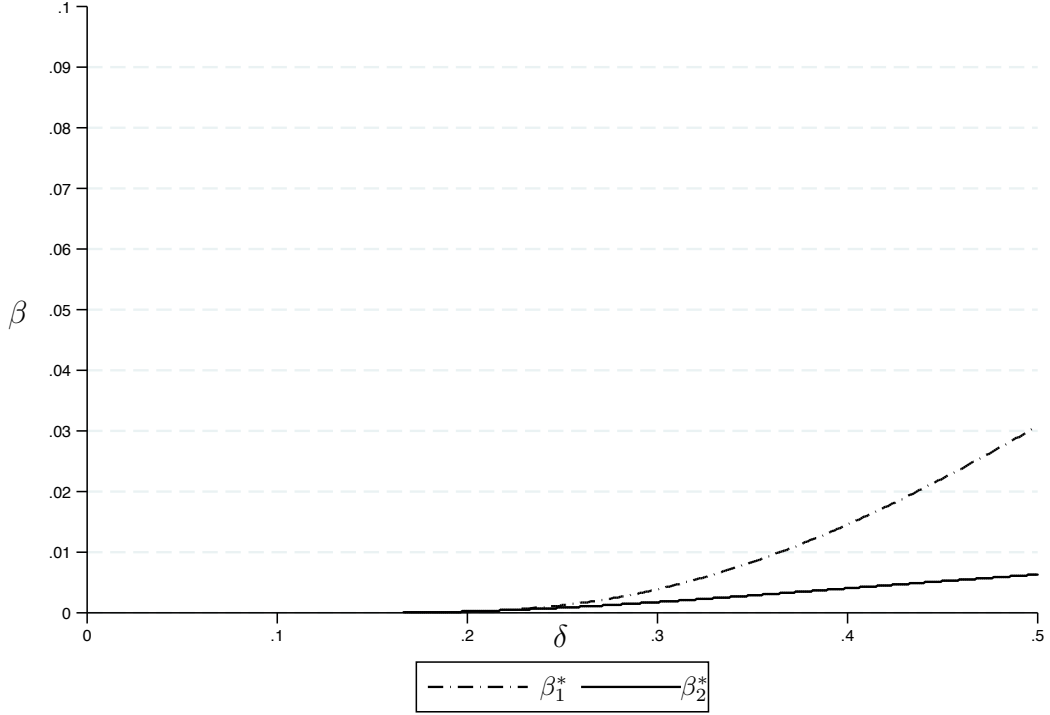


Figure 2.8: Number of integrations under preemption - Hypothesis 1

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. For readability, values above $\beta = 0.1$ 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.

separated firm in the asymmetric case 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.

2.5.2 Merger game under Hypothesis 2

In this section, I 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 2.4: 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} .²¹

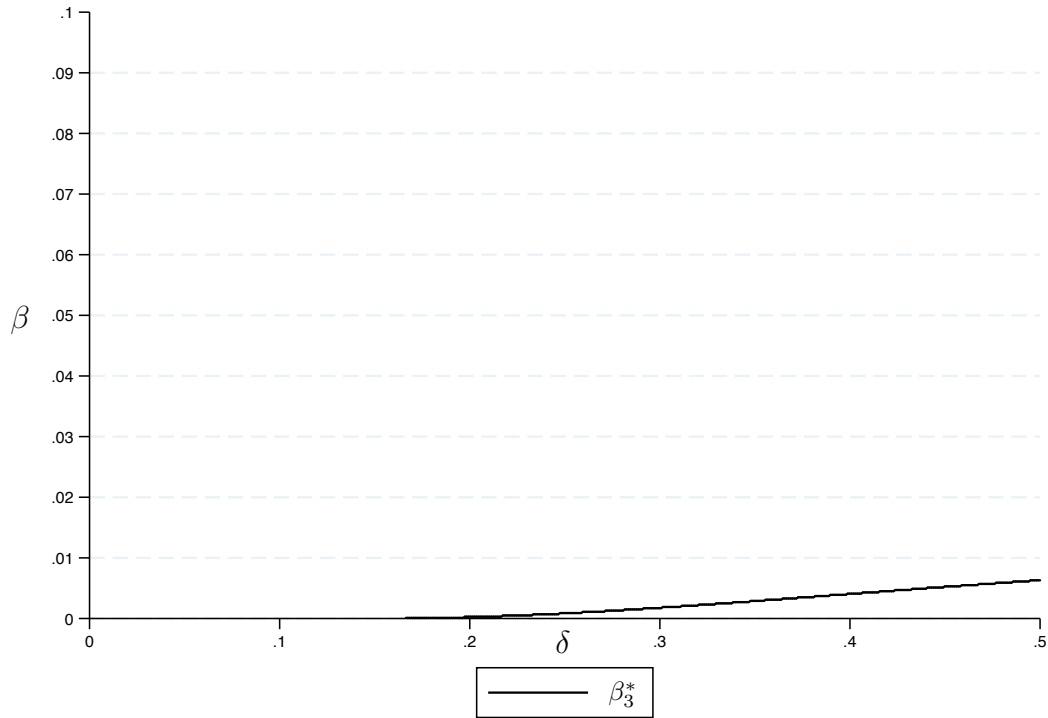


Figure 2.9: Number of integrations under preemption - Hypothesis 2

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. For readability, values above $\beta = 0.1$ 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 earns 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.²² 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

²¹The observations previously made still hold (i.e. $\Pi_{VS} < \Pi_{VI}$ for all parameters). The following results holds for $M = 1$, $r = 0.03$ and $\alpha = 0.8$, but are robust to parameterisation changes, as shown in Appendix 2.C. Hence, I directly draw the final group graph, Figure 2.9.

²²Indeed, as shown in Chapter 1, the closer to its precommitment timing a firm adopts, the higher the profits.

equilibrium, crucially depends on the equilibrium selection. Still, such investigation showed that the existence of the asymmetric equilibrium does not rely on the type of game, and may occur under some circumstances.

2.6 Welfare Analysis

In this section, I develop a welfare analysis: do integrations harm consumer and total surplus? Hence, 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, $Q^2/2$.²³

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

$$cs_i = \int_0^{T_1^i} \frac{(q_i^0 + q_j^0)^2}{2} e^{-rt} dt + \int_{T_1^i}^{T_2^j} \frac{(q_i^l + q_j^f)^2}{2} e^{-rt} dt + \int_{T_2^j}^{\infty} \frac{(q_i^b + q_j^b)^2}{2} e^{-rt} dt \quad (2.6)$$

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.

2.6.1 Welfare Analysis under the Precommitment game

A first step is then to compare consumers' surplus under the different *laissez-faire* equilibria. 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 case respectively can be written as follow.²⁴

$$\begin{aligned} CS_{VS} &= p_{VS} p_{VS} cs_{VS}^{11} + 2p_{VS}(1 - p_{VS})cs_{VS} + (1 - p_{VS})(1 - p_{VS})cs_{VS}^{22} \\ CS_{VI} &= p_{VI} p_{VI} cs_{VI}^{11} + 2p_{VI}(1 - p_{VI})cs_{VI} + (1 - p_{VI})(1 - p_{VI})cs_{VI}^{22} \\ CS_{AC} &= p_{AI} p_{AS} cs_{AC}^{11} + p_{AI}(1 - p_{AS})cs_{AI} + (1 - p_{AI})p_{AS}cs_{AS} + (1 - p_{AI})(1 - p_{AS})cs_{AC}^{22} \end{aligned} \quad (2.7)$$

It is then possible to compare the different consumer surplus, to determine which situation is preferred by consumers. However, such a comparison again involves a non-analytical solution. Simulations are discussed, under the same parameterisation as for the merger game. Graphical exposition is presented in Figure 2.10. For the chosen parameterisation, the vertically integrated case is only preferable for very

²³This is a standard result from Cournot competition.

²⁴For the asymmetric case, I apply also the same strategy developed in Appendix 2.A.

extreme values of β and δ .

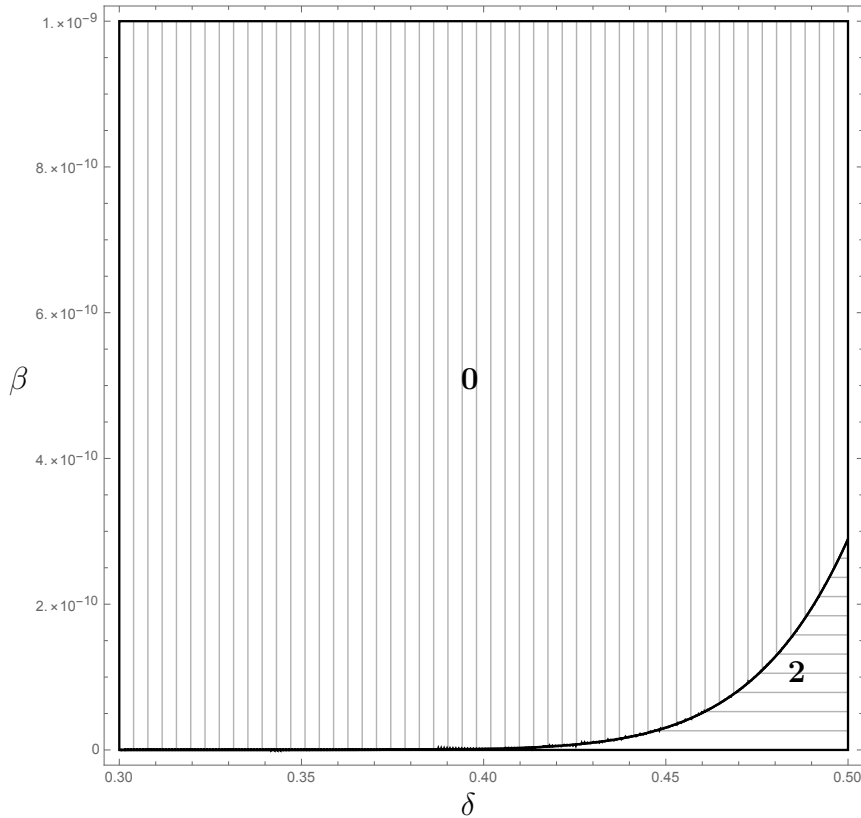


Figure 2.10: Number of integrations maximising Consumers' Surplus - Precommitment

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. This graph is restricted to values of β below 10^{-9} and values of δ above 0.1 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.

Proposition 2.2. *There exists a range of parameter values for which the vertically integrated set-up maximises consumer surplus only if the upstream bargaining power is extremely low and the effectiveness of the technology very high. Otherwise, consumer surplus is maximised under the vertically separated set-up.*

Proof. This result comes from simulations using the timing of adoption described in Chapter 1, the expected consumer surplus functions described in equations (2.7) and the equilibrium selection strategy described in Appendix 2.A. $\square$

The intuition for this result is as follows. From the consumers' point of view, the preferred market set-up is the one yielding the highest output. Using Table 2.1, one can compute the total quantities under the different set-ups and different timings of adoption. Assuming for now that the timings of adoption was the same under the three set-ups, one can observe that $Q_{VS} \geq Q_{AC} > Q_{VI}$. This is the

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 set-up can still be preferable than the two other set-ups, for the parameter values depicted in Figure 2.10. This possibility comes from the timing of adoption. For all set-ups, the more technology adoptions, the higher the total quantity. Therefore, the consumers' ideal timing of adoption would be that both firms adopt at the same time and as early as possible. For area 2 depicted in Figure 2.10, both adoptions occur earlier under the vertically integrated case, compared to the asymmetric case and the vertically separated case. In addition, 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 adoptions occur 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 occur for such parameter values under the asymmetric case.

If the objective of a competition authority is to maximise consumer surplus, it should forbid any integration unless the technology is very effective and the upstream bargaining extremely low. In other 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.²⁵

Now I discuss 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 consists in the addition of the different expected pay-offs computed previously.

$$SW = CS + \Pi_A + \Pi_B \quad (2.8)$$

where both profits and consumer surplus are the expected ones. A graphical exposition is presented below, in Figure 2.11. 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 2.11 is quite similar to Figure 2.10: the different

²⁵The previous results are robust to changes in α , M and r . Replications of Figure 2.10 under different parameterisation are presented in Appendix 2.C

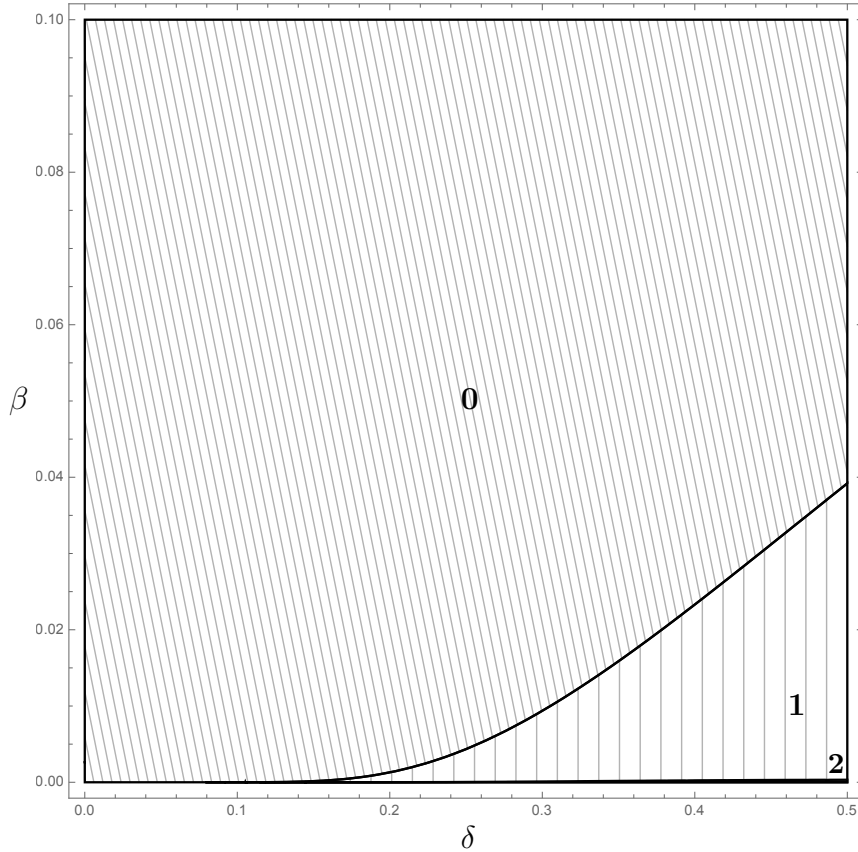


Figure 2.11: Number of integrations maximising Social Welfare - Precommitment

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. This graph is restricted to values of β below 0.1 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.

areas slightly changed in size, but not in location.

Proposition 2.3. *There exist a range of parameter values such that 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 does so for extremely low values of β .*

Proof. This result comes from simulations using the timing of adoption described in Chapter 1, the expected profit and consumer surplus functions described in equations (2.7) and (2.9) and the equilibrium selection strategy described in Appendix 2.A. $\square$

A socially optimal set-up is a situation that reaches the best trade-off between maximising the consumer surplus on the one hand and the industry profits on the other hand. From the previous proposition we know what consumers prefer: the

vertically separated case first, then the asymmetric case and finally the vertically integrated case. In terms of total profits, the ranking is the exact opposite (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.²⁶ Thus, one can observe that the preferences of the consumers and the industry are in conflict, and the balance of these preferences yield the areas depicted in Figure 2.11.

Finally, the comparison of the areas depicted in Figure 2.7 and 2.11 allows to determine whether the market naturally reaches the socially optimal outcome. Such comparison shows that area 1 of Figure 2.7 is smaller and included in area 1 of Figure 2.11, whereas area 0 and area 2 of Figure 2.11 are smaller and included in the ones of Figure 2.7 respectively.

Corollary 2.1. *There exists a range of parameter values such that:*

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

Proof. This result comes from Propositions 2.1 and 2.3. □

The above examples suggest 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 2.11 overlapping the area 0 of Figure 2.7 and preventing the second integration in the area 1 of Figure 2.11 overlapping the area 2 of Figure 2.7.²⁷

2.6.2 Welfare Analysis under the Preemption game

In this section, I develop a welfare analysis under the preemption game. Using the timings derived in Chapter 1 and the same definitions of consumer surplus and social

²⁶Such statement involves simulations, but since the intuition is simple, graphical exposition is skipped.

²⁷The previous results are robust to changes in α , M and r . Replications of Figure 2.11 under different parameterisation are presented in Appendix 2.C

welfare as above, I can compute consumer surplus and social welfare, since in the preemption game, there are no equilibrium selection issues (i.e. only the timing of adoption is needed for consumer surplus, and both payoffs are included in the total surplus).

First I investigate the consumer surplus. Consumers always prefer the vertically separated case.²⁸

Proposition 2.4. *Under the preemption game, there exists a range of parameter values for which integration always decreases the consumers' welfare: the symmetric vertically separated outcome is always preferred by consumers.*

Proof. This result comes from simulations using the timing of adoption described in Chapter 1 and the consumer surplus functions described in equation (2.6). $\square$

The possibility of simultaneous early adopting that existed in the precommitment game does not exist here anymore. In addition, when β is low, the *bargaining* effect, which causes late adoption under vertical separation, is compensated by the *preemption* effect, which drives faster adoption under symmetric set-ups. Hence, vertical separation is the preferred set-up of consumers, since it generates both high quantities and early adoptions due to strong preemption incentive.

Concerning social welfare, the conclusion is more complex. Figure 2.12 represents the different parameter values for which a set-up is socially preferred or not.

Proposition 2.5. *Under the preemption game, there exists a range of parameter values for which 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 .*

Proof. This result comes from simulations using the timing of adoption described in Chapter 1 and the consumer surplus and profit functions described in equations (2.6) and (2.2). $\square$

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 2.12 and the Figures 2.8 and 2.9, in order to see whether the merger game outcomes match the socially preferred ones.

²⁸This holds for the current parameterisation but also for other ones (see Appendix 2.C).

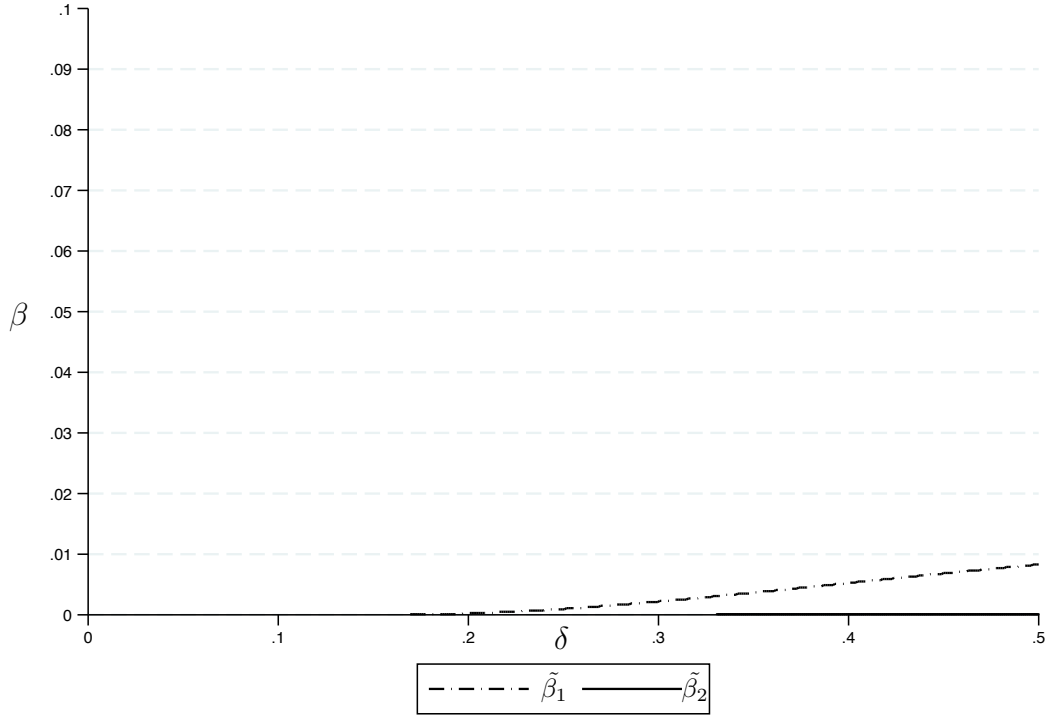


Figure 2.12: Social Welfare under preemption

Note: In this graph, the parameterisation is the following one: $M = 1$, $r = 0.03$ and $\alpha = 0.8$. For readability, values above $\beta = 0.1$ 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.

Corollary 2.2. *Under the preemption game, there exists a range of parameter values for which:*

- *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 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.

Proof. This result comes from Proposition 2.5 and the equilibria described in Section 2.5. □

Let's discuss Corollary 2.2. Under Hypothesis 2, the asymmetric case is never chosen by the market, whereas society would prefer it for some range of parameters. Hence, within that 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, the above results suggest two types of competition policy. The first one, 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.

2.7 Conclusion

In this chapter, I developed a model where two vertical structures decide whether to integrate first and when to adopt a cost-reducing technology second, and finally compete in quantity then. The combination of such features allows to show the effect of an integration on the timing of adoption on the one hand, and how the presence of a cost-reducing technology may affect integration incentives on the other hand.

The study of the asymmetric case reveals the two main drivers of technology adoption: a *bargaining* effect and a *strategic* effect. The first one relates to the capacity of the adopter to capture the benefits from adoption depending on its bargaining power, whereas the second one relates to the capacity of a vertically separated firm

to use below-cost wholesale pricing to maximise its profits. Hence, due to this latter effect, the impact of integration on the timing of adoption is influenced by the vertical structure of the competitor. My contribution is then threefold.

First, combining the features of a merger game and a technology adoption game allowed me to show the existence of an asymmetric equilibrium, where one firm chooses to integrate while the other one remains separated, in a purely symmetric set-up, without any synergies or foreclosure incentives. More specifically, I show that, due to the *strategic* effect, the profitability of integration differs when the competitor is separated compared to when it is integrated, and this difference in incentives between the first and the second integration can yield an asymmetric integration outcome.

Second, the above results are robust to a change in the type of adoption game. Even under the preemption game, an asymmetric equilibrium may arise due to a *preemption* effect which provides stronger incentives to integrate when the competitor is separated compared to when it is integrated.

Finally, from a competition policy perspective, I determined whether a competition authority should allow vertical integration or not. Considering consumer surplus only, such a competition authority should generally prevent integration, as vertical separation yields the highest output, but if it considers social welfare, on the contrary, it should not intervene in many cases. This 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 shape of the vertical relations within an industry determines its performance in innovative terms, and on the other hand, the presence of innovative processes in an industry considerably affects its vertical structure. Hence, this work supports the view that competition authorities should take into account the relationship between vertical structure and innovative activities when assessing vertical mergers.

There is ample scope for future empirical research. It would be very interesting to develop a structural model that takes into account both integration and adoption decisions when performing a vertical merger simulation. Integrations in the “TMT” sector could provide very relevant and concrete cases to investigate. For example, the recent *KPN/Reggefiber* case (2014) showed how the adoption of optic fibre can be a driver of vertical integration in the telecommunications market.²⁹

²⁹Source: *KPN/Reggefiber*, Case 14.0672.24, ACM Decision of 31/10/2014.

Appendix

2.A Discussion: the Equilibrium Selection in the Precommitment Game

In this Appendix, I discuss the issue of equilibrium selection in the precommitment game. 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 2.2 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 the relevant expected profits. The first approach yields trivial results: the profitability of integration results from which pay-off the firm fully anticipates.

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.³⁰

Using Equation (2.5), I can now allocate a given probability to each situation (i.e. each entry of Table 2.2) and then compute expected joint profits associated with each set-up.³¹ Therefore, assuming firms are risk-neutral, expected pay-offs will take

³⁰Read Harsanyi (1973) and the purification theorem for further justification of the mixed-strategy equilibrium.

³¹The reader should note that in the separated case, upstream profits are included in the probabilities (equation (2.5)), but joint profits are then plugged in equation (2.9).

the form:

$$\begin{aligned}\Pi_A &= p_A p_B \Pi_A^{11} + p_A(1 - p_B) \Pi_A^1 + (1 - p_A) p_B \Pi_A^2 + (1 - p_A)(1 - p_B) \Pi_A^{22} \\ \Pi_B &= p_A p_B \Pi_B^{11} + p_A(1 - p_B) \Pi_B^2 + (1 - p_A) p_B \Pi_B^1 + (1 - p_A)(1 - p_B) \Pi_B^{22}\end{aligned}\quad (2.9)$$

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.

Indeed, in the asymmetric case, the situation is more complicated, because most of the time, $T_1^{AI} \neq T_1^{AS}$ and $T_2^{AI} \neq T_2^{AS}$. This may yield situations where, in Table 2.2, $\Pi_i^1 < \Pi_i^{22}$ or $\Pi_i^2 < \Pi_i^{11}$. In these cases, p_i can be lower or equal to zero (or take values above one). This possibility arises because, in the precommitment game, the pure strategy equilibria are computed given a specific technology position. For instance, T_1^i is the best strategy given that the firm adopts first. In the mixed strategy, the technology position is no longer given. Hence, one must compare the profits when adopting at T_1^i to the ones when adopting at T_2^i . There might be some situations where it is profitable to always play T_1^i or T_2^i . I consider all the possible scenarios in the following subsection. Figure 2.A.1 depicts the ranges of parameter values characterizing the possible situations.

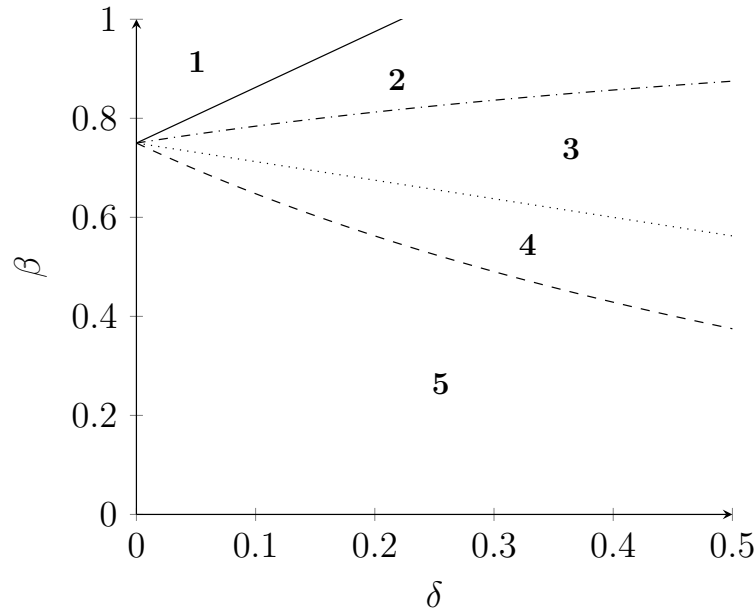


Figure 2.A.1: Asymmetric Case: Timing of Adoption and Mixed Strategy

Note: In area 1, the only equilibrium is the one where AS leads. In area 2, both equilibria exist, and $T_1^{AI} > T_1^{AS}$ and $T_2^{AI} > T_2^{AS}$. In area 3, both equilibria exist, and $T_1^{AI} < T_1^{AS}$ and $T_2^{AI} > T_2^{AS}$. In area 4, both equilibria exist, and $T_1^{AI} < T_1^{AS}$ and $T_2^{AI} < T_2^{AS}$. In area 5, the only equilibrium is the one where AI leads.

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 Proposition 1.1, 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 curves separating these zones indicates the parameter values for which $T_1^{AI} = T_1^{AS}$ (the upper dashed-dotted line) and for which $T_2^{AI} = T_2^{AS}$ (the lower dotted 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,³² 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. 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 market selects the pure strategy equilibrium in which AS leads; 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 (2.9). 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 market selects the pure strategy equilibrium in which AI leads; 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 (2.9).

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 market selects the pure strategy equilibrium in which AS leads; 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 market selects the pure strategy equilibrium in which AI leads; 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 (2.9). Finally, I obtain a single pay-off Π_{AS} and Π_{AI} for

³²The profits as a leader (follower) are strictly concave in time, and T_1 (T_2) is the only global maximum.

every zone depicted in Figure 2.A.1.

2.B Discussion: the Impact of Integration on the Time Lapse between Adoptions

In this Appendix section, the impact of integration on the time lapse between adoptions under the precommitment game is described. This analysis is particularly relevant when evaluating the profitability of integration. As a matter of fact, the time lapse between adoptions corresponds to the number of periods during which the technology leader will benefit from its competitive advantage. Hence, if integration makes this time lapse bigger, it will affect the profitability of this operation. In the following, I compute the parameters' threshold such that below or above it, integration makes time lapse larger. These conditions are obtained from the first order conditions in Table 2.1. Overall, under the precommitment game, integration increases the time span between first and second adoption whenever β is low.

2.B.1 Impact of Integration when the Competitor is Separated

$$\begin{aligned}
 T_1^{VS} - T_2^{VS} < T_1^{AI} - T_2^{AS} &\Leftrightarrow 0 \leq \beta < \beta_1^{**} \equiv \frac{75(2+3\delta)}{8(25+48\delta)} \quad \text{and} \quad 0 < \delta \leq 1/2 \\
 T_1^{VS} - T_2^{VS} < T_1^{AS} - T_2^{AI} &\Leftrightarrow \beta_2^{**} \equiv \frac{75(2-\delta)}{8(25-23\delta)} < \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2
 \end{aligned}
 \tag{2.10}$$

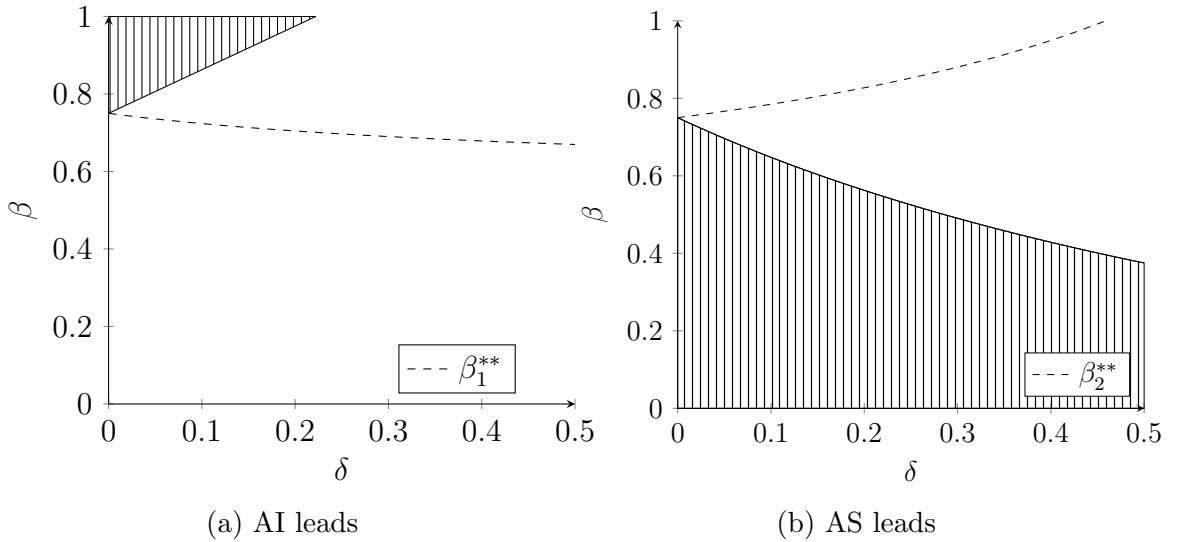


Figure 2.B.1: Comparison of Time Span: VS v. Asymmetric Case

Note: The stripped area corresponds to the parameter values for which the equilibrium in the asymmetric case does not exist. (a) For the values of β and δ below the dotted line, integration increases the time span between adoptions. (b) For the values of β and δ above the dotted line, integration increases the time span between adoptions.

2.B.2 Impact of Integration when the Competitor is Integrated

$$\begin{aligned}
 T_1^{VI} - T_2^{VI} < T_1^{AI} - T_2^{AS} &\Leftrightarrow 0 \leq \beta < \beta_3^{**} \equiv \frac{54 + 17\delta}{72} \quad \text{and} \quad 0 < \delta \leq 1/2 \\
 T_1^{VI} - T_2^{VI} < T_1^{AS} - T_2^{AI} &\Leftrightarrow \beta_4^{**} \equiv \frac{54 + 37\delta}{72(1 + \delta)} < \beta \leq 1 \quad \text{and} \quad 0 < \delta \leq 1/2
 \end{aligned}
 \tag{2.11}$$

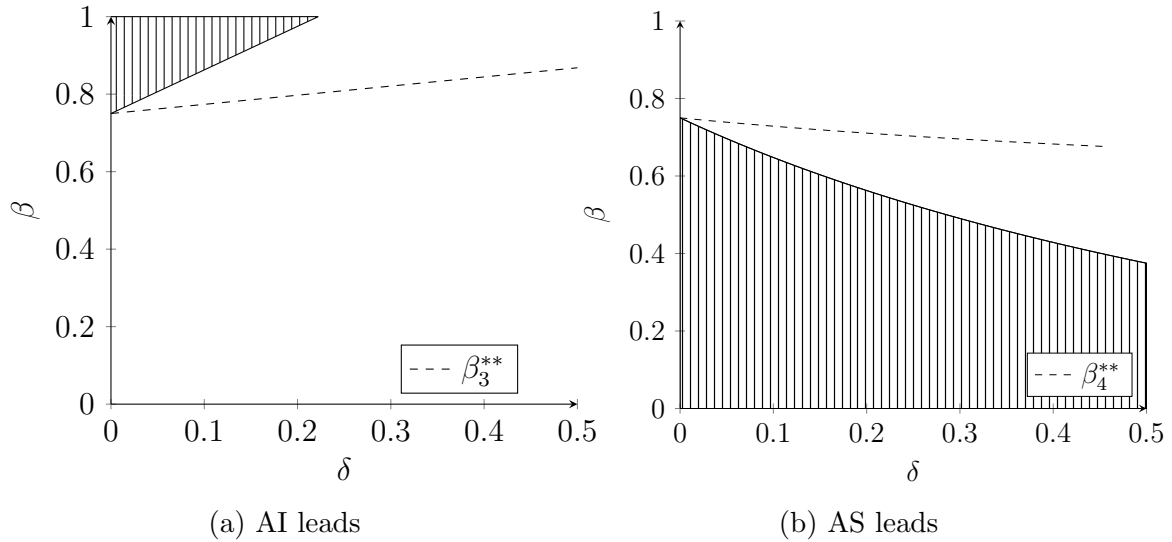


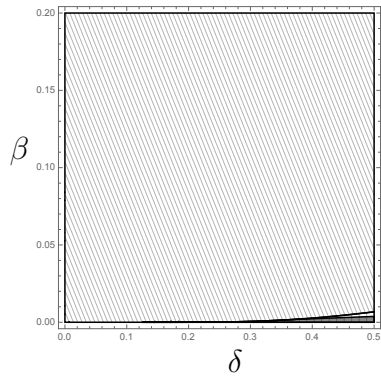
Figure 2.B.2: Comparison of Time Lapse: Asymmetric Case v. VI

Note: The stripped area corresponds to the parameter values for which the equilibrium in the asymmetric case does not exist. (a) For the values of β and δ above the dotted line, integration increases the time span between adoptions. (b) For the values of β and δ below the dotted line, integration increases the time span between adoptions.

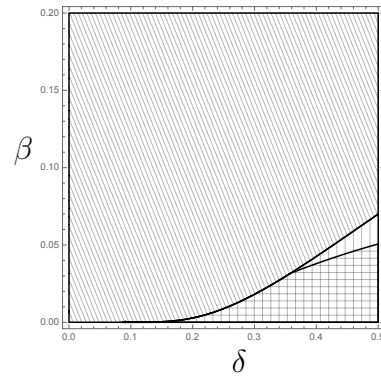
2.C Robustness Check: Alternative Parameterisations

In this section, I discuss the influence of the parameterisation on the results of this chapter. 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

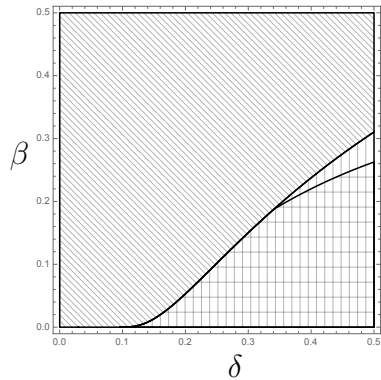
adoption. It may change slightly the shape of the positive zones depicted before, but it doesn't affect qualitatively the previous interpretations and results.



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



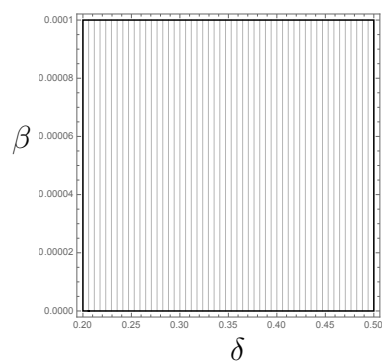
(b) $M = 0.5$, $\alpha = 0.42$ and $r = 0.03$



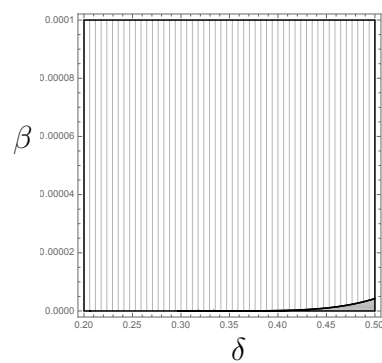
(c) $M = 1$, $\alpha = 0.42$ and $r = 0.1$

Figure 2.C.1: Number of Integrations under Different Parameterisations

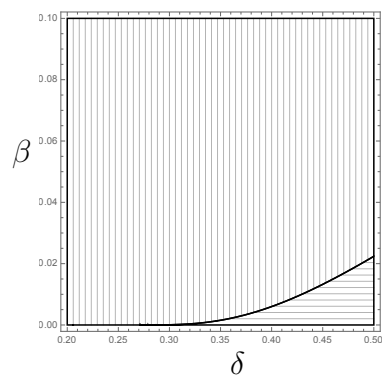
Note: These graphs are replications of Figure 2.7 under different parameterisations.



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



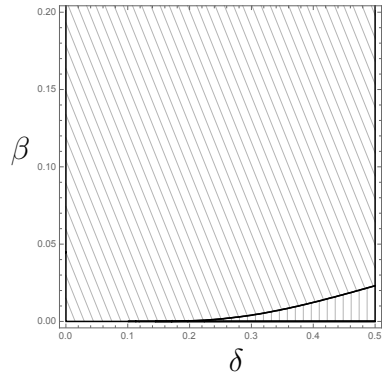
(b) $M = 0.5$, $\alpha = 0.42$ and $r = 0.03$



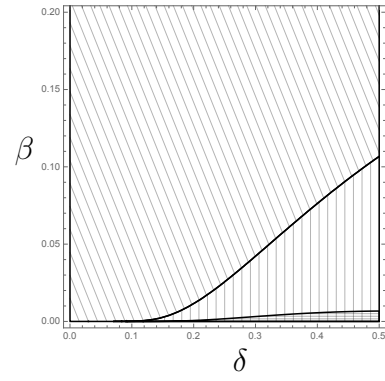
(c) $M = 1$, $\alpha = 0.42$ and $r = 0.1$

Figure 2.C.2: Consumers' Surplus under Different Parameterisations

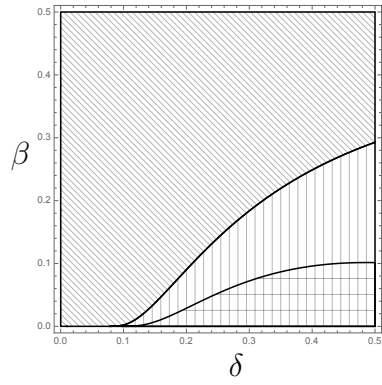
Note: These graphs are replications of Figure 2.10 under different parameterisations.



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



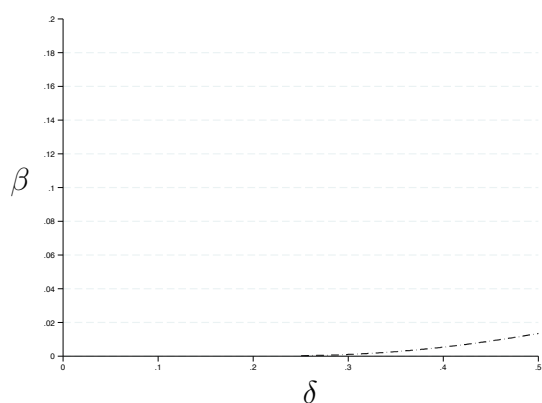
(b) $M = 0.5$, $\alpha = 0.42$ and $r = 0.03$



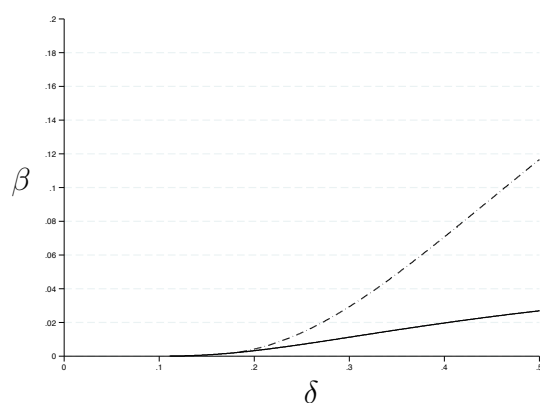
(c) $M = 1$, $\alpha = 0.42$ and $r = 0.1$

Figure 2.C.3: Social Welfare under Different Parameterisations

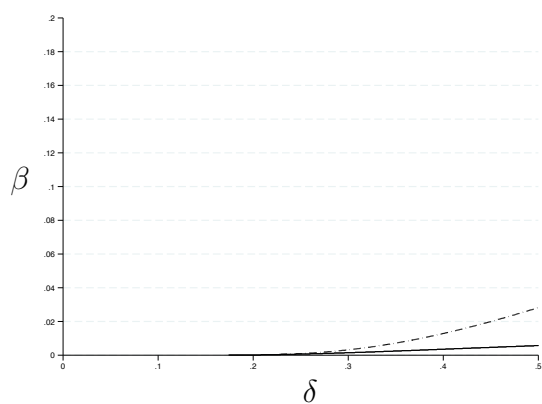
Note: These graphs are replications of Figure 2.11 under different parameterisations.



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



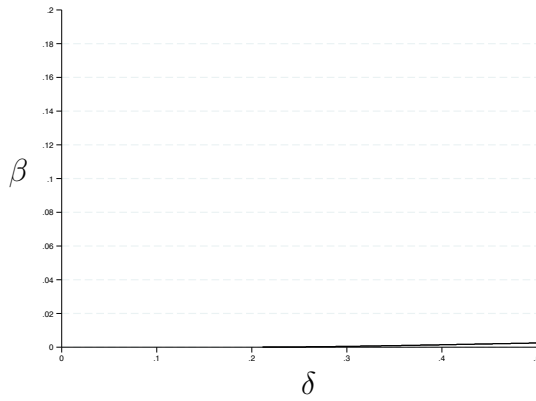
(b) $M = 1$, $\alpha = 0.8$ and $r = 0.05$



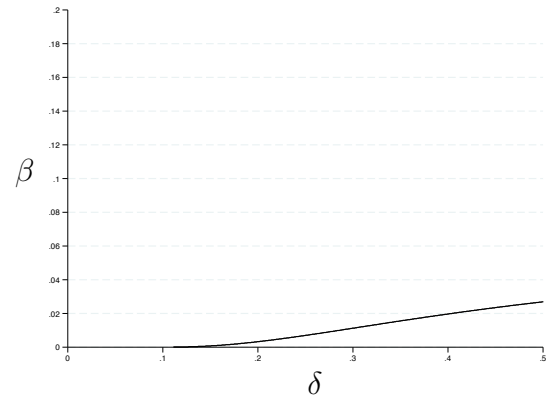
(c) $M = 0.5$, $\alpha = 0.8$ and $r = 0.03$

Figure 2.C.4: Merger Game Equilibria under Preemption - Hypothesis 1

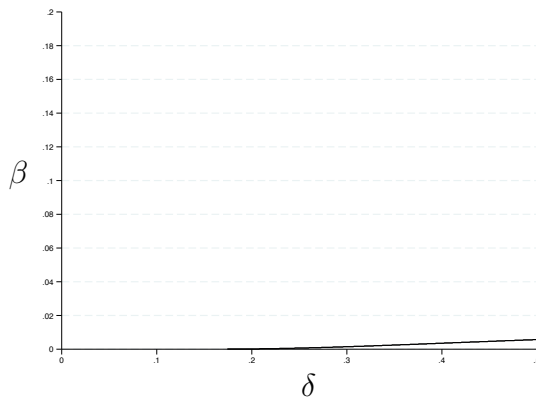
Note: These graphs are replications of Figure 2.8 under different parameterisations.



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



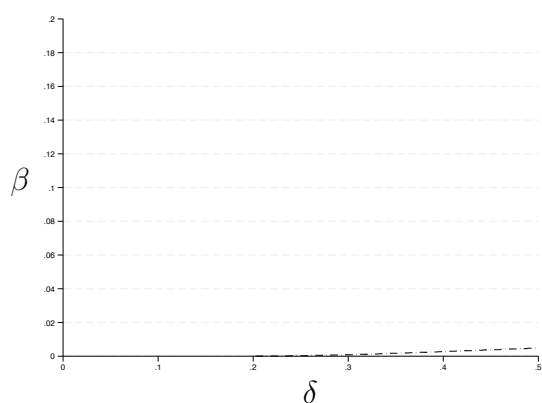
(b) $M = 1$, $\alpha = 0.8$ and $r = 0.05$



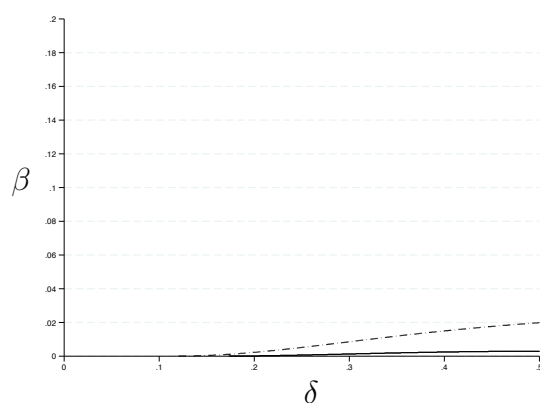
(c) $M = 0.5$, $\alpha = 0.8$ and $r = 0.03$

Figure 2.C.5: Merger Game Equilibria under Preemption - Hypothesis 2

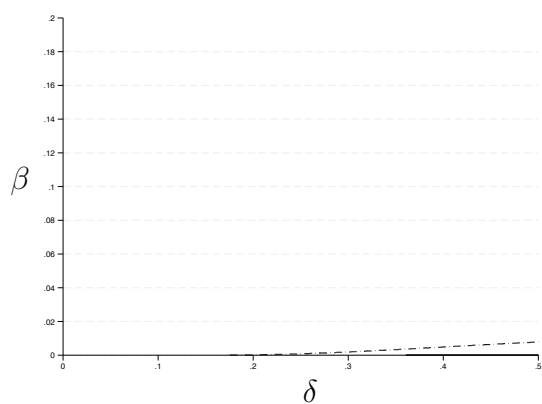
Note: These graphs are replications of Figure 2.9 under different parameterisations.



(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 2.C.6: Social Welfare under Preemption

Note: These graphs are replications of Figure 2.12 under different parameterisations.

Chapter 3

Retail Apocalypse Now: A Theory of Predatory Investment

We first measure ourselves in terms of the metrics most indicative of our market leadership: customer and revenue growth[...]. We have invested and will continue to invest aggressively to expand and leverage our customer base, brand and infrastructure[...].

Jeffrey P. Bezos, Letter to Shareholders, Amazon.com, Inc. (March, 30th 1998)

3.1 Introduction

The Retail Apocalypse is a term used to describe the sharp increase in closures and bankruptcies of Brick-&-Mortars since the start of 2017 in North America.¹ It is a phenomenon that is increasing in size and spreading to other developed countries, such as the United Kingdom or South Africa. If the use of such a label is sometimes disputed, the importance of the Retail Apocalypse is now uncontested.

According to Coresight Research, the number of retailer closures are consistently higher than the number of retailer openings in the USA since 2017, as represented in Figure 3.1.

These closures affect many types of retailing. For instance, the “apparel, footwear

¹For the rest of this chapter, we will talk about the pre covid-19 period.

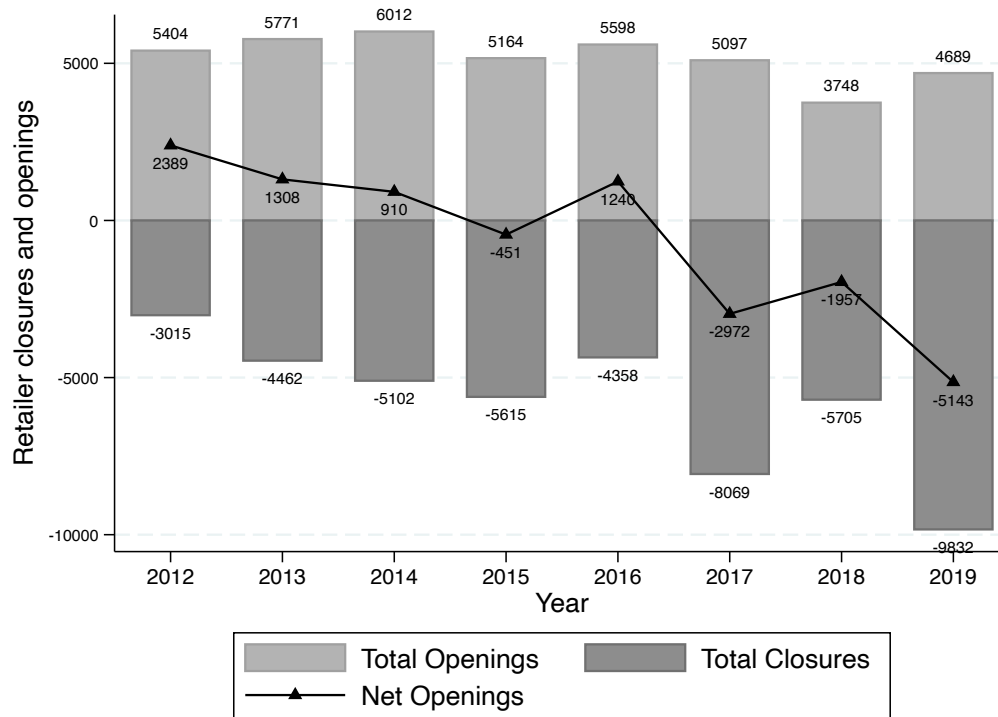


Figure 3.1: Retailer Closures and Openings per Year (USA, 2012-2019)

Source: Coresight Research. Note: Coresight’s experienced analysts curate a dynamic list of approximately 400 retailers to represent the overall US retail market. They utilize their industry expertise to adjust this list on a periodic basis to reflect key trends occurring in retail. The proprietary Coresight Research Retail Store Databank reflects store closures and openings of retailers.

and accessories” sector experienced an average of -2932 net openings per year over the period 2017 to 2019, compared to -227 over the previous three years. The “department stores” sector experienced an average of -195 net openings per year over this period compared to 19 over the previous one. The “grocery retailers” sector experienced an average of -202 net openings per year compared to 243 over 2014 to 2016. Some brands, such as Payless, closed all their US retail outlets.²

The roots of the Retail Apocalypse are still debated, and one challenge is to understand why is it happening only now (i.e. since 2017). One possible explanation is the excessive construction of shopping malls since the 1970s in North America, where the retail floorspace per capita far exceeds anywhere else. A second one is the shift of consumer habits towards online shopping, especially towards the “giants” of e-commerce, such as Amazon.com (“Amazon”). However, these two arguments alone fail to explain the size and the timing of this phenomenon. On the one hand, the excessive amount of shopping malls is an exclusively American issue, whereas the Retail Apocalypse also affects, say, the UK. On the other hand, online shopping has been widely used for the past 20 years, and its existence alone cannot explain

²Source: Coresight Research. URL: <https://coresight.com>

why the Retail Apocalypse started only very recently.

In this paper, I show that the recent non-price strategies of internet platforms such as Amazon could have resulted in the exclusion of physical rivals from the retailing market, and therefore contributed to the current Retail Apocalypse. This claim is motivated by two main observations. The first one is that Amazon, the worldwide leader of e-commerce, has not been making any consistent profits for the past 20 years (i.e. until 2016) despite the explosion of its revenues, as shown in Figures 3.2 and 3.3.

Figure 3.2: Amazon Profits and Revenues

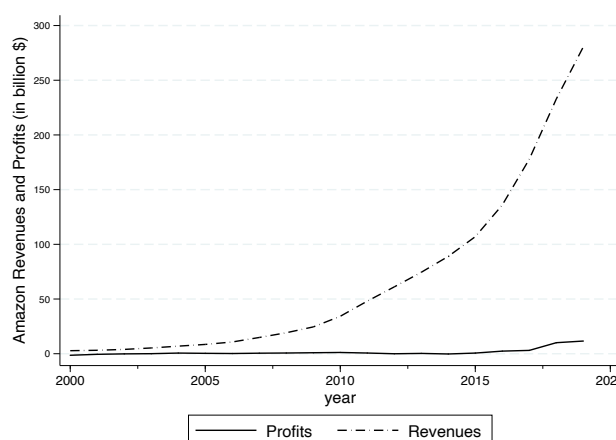
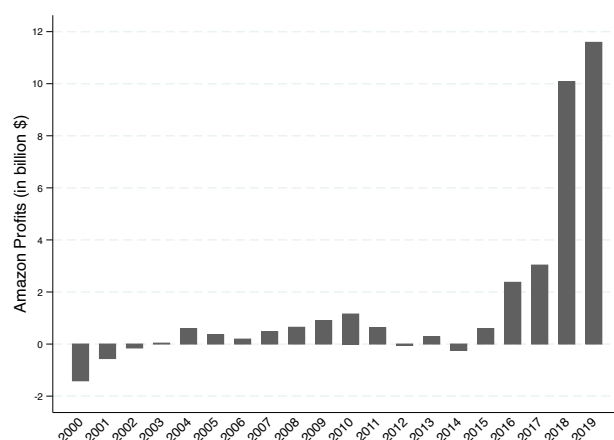


Figure 3.3: Amazon Profits



Source: Amazon SEC Filings.

Indeed, Amazon experienced its first substantial profits during the period from 2016 to 2019, which matches the timeframe of the Retail Apocalypse. The second observation motivating this work is that Amazon's delivery costs are becoming more and more important, as shown in Figures 3.4 and 3.5.

These figures show that not only are shipping costs increasing much faster than shipping revenues,³ but also that these costs represent an increasing share of total revenues since 2010. Hence, up to 2010, Amazon became more and more efficient at delivering its products, which follows the usual mechanism of scale economies, but after this date, deliveries became an increasing burden that now exceeds its 2000 level.

Ultimately, this paper aims to explain why Amazon is expanding its physical presence, especially since the start of the Retail Apocalypse. Throughout its existence, Amazon acquired many firms, and perhaps one of its most famous acquisitions is Whole Foods Market, in 2017. In addition to mergers with some physical retailers,

³Amazon Prime memberships and all delivery fees paid by customers are included in shipping revenues.

Figure 3.4: Amazon Shipping Costs and Revenues

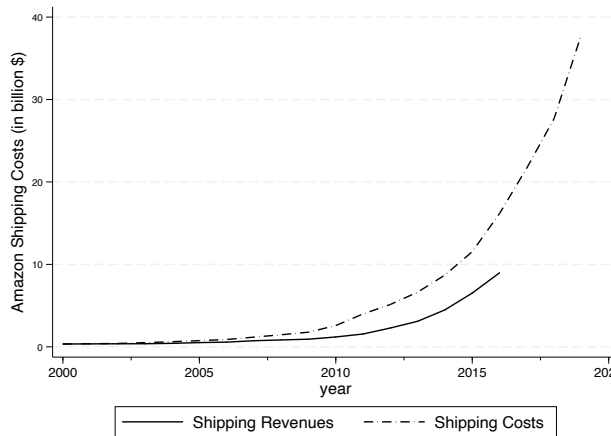
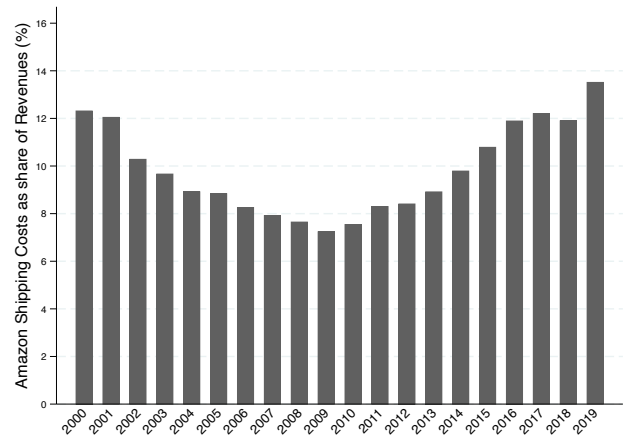


Figure 3.5: Amazon Shipping Costs as Share of Revenues



Source: Amazon SEC Filings. Note: Information for shipping revenues is provided up to 2016 only.

it also introduced its own physical retail outlets. The most notable ones are Amazon Go and Amazon 4-Star, in 2018. Amazon Go is a type of convenience store in which there are no cashiers, and a system of cameras detect which products you pick and charges your Amazon account directly. Amazon 4-Star is a type of retailer selling goods rated four stars or above on Amazon website. Hence, Amazon chose to expand its activities to physical retailing while this sector was (and still is) going through one of its biggest crises.

From these observations, I build a theoretical model linking and explaining such patterns. I study the (price) competition of an online retailer and a physical retailer selling a homogeneous good. The physical shop is located in the middle of a linear segment along which a unit mass of consumers is distributed. The location of the online firm is irrelevant as it delivers its product to the consumer's location. Consumers are uncertain about their valuation of the good, and visiting the physical store allows them to "experience" the good before purchase (and solve their uncertainty). However, they incur a transportation cost they would not pay by shopping directly online. Buying online involves a waiting cost due to delivery time, but the online firm can invest in order to reduce this waiting cost.

Consumers are differentiated in terms of two parameters: patience and location. Patience determines the cost of waiting for an online delivery, and location determines the cost of visiting the physical shop. Depending on these two parameters, three types of consumption channels arise (other than no consumption): online, local and switching consumers. Online consumers order directly online, do not solve the uncertainty about their valuation of the good and experience waiting time, but

save transportation costs and expect to pay a cheaper price.⁴ Local consumers visit the physical shop, resolve uncertainty and obtain the good immediately. However, they incur a travelling cost, and expect to face a higher price. Finally, switching consumers visit the shop to solve uncertainty, but order online (with no switching cost), in order to benefit from the expected lower online price. However, they incur both travelling and waiting cost. A third and final parameter is the probability of having a positive experience from the good. It is exogenous and identical for all consumers, and all results will be presented as a function of this probability.

I study the pricing and investment strategies of an online retailer and a physical shop facing such demand. First, I study a static model where both firms have zero (marginal or fixed) cost and where both prices and investment are set simultaneously and non-cooperatively. I compare equilibrium prices and profits to the one in the benchmark case where no investment is allowed. My first result is to show that the presence of investments does not affect significantly the price or profits levels, as investment level remains quite low in this static set-up. In other words, I show that the nature of the competition itself between online and physical retailers do not justify the important delivery costs of Amazon, its low profitability for so many years nor the Retail Apocalypse. Without the possibility of exclusion and payback, investments in delivery services remain very low and both firms are profitable.

Then, I study a two-period model where the aforementioned firms compete in prices. The online firm is assumed to be active during both periods and still has zero costs. The physical shop is active during the first period, but has to pay a fee to remain active during the second period (e.g. rent). If its first period profits are less or equal to this fixed fee, it leaves the market at the end of period one. My second result is the following one: if the online firm is patient enough, it can find it profitable to exclude its physical competitor by setting a high investment level and a low price during the first period and benefit from monopoly profits during the second period. This predation strategy matches the stylised facts mentioned earlier: the low profitability of Amazon, its high investment in delivery services, and the closure of physical retail outlets.

Finally, I further investigate the recoupment period, which is the period after the exclusion of the physical shop. I study two possible types of predation strategy: one with replacement, and one without. The predation with replacement scenario corresponds to the case in which the online firm builds (or buys) a physical store during the second period at the location where the excluded physical competitor

⁴For the ease of exposition, online prices are assumed to be lower than physical ones, but prices are endogenous in the model.

was.⁵ Without replacement, the online firm operates only online during the second period. My third result is to show that, once the physical competitor is excluded, the online firm finds it profitable to build (or buy) a physical retailer only when the probability to have a positive experience from the product is high. Interpreting Amazon ratings above four stars as a high probability to have a positive experience from the product, this result matches Amazon's recent strategy with Amazon 4-Star shops. Additionally, I investigate alternative distributions over the location line, and when the store is located at the most densely populated area, the online firm finds predation significantly more profitable when it replaces the physical store. This also matches the fact that these shops are located in the most densely populated areas of the USA (e.g. Manhattan).

Ultimately, I study the effect of predation on welfare. For low discount factor, consumers prefer predation to accommodation. They also prefer predation with replacement compared to without. However, when considering the total surplus, predation generally harms welfare.

In addition, I consider several extensions. On the one hand, I show that a limit pricing strategy consisting in maintaining predatory price and investment levels after the competitor's exit is unprofitable. Hence, once should not expect an online firm to maintain high delivery costs and low prices forever. On the other hand, I show that such predation strategy is less costly than a standard merger procedure.

This work touches on several literatures. First, this work contributes to the predation literature, as I consider a model of predatory investment (e.g. Besanko et al. (2014), Vasconcelos (2015), Argenton (2019)).⁶ This work fits in the consumer search literature, in which consumers have to visit different firms in order to solve uncertainty about prices or valuations (e.g. Garcia et al. (2017), Garcia and Shelegia (2018), Petrikaitė (2018)).⁷ I contribute to this literature by considering a framework where shops are heterogeneous in terms of information they can provide to consumer, and where visiting one shop is costly but switching is costless. This work also fits in the consumer loss aversion literature, which develops models where the consumer is uncertain about its valuation of the good and is averse to negative experiences (e.g. Puppe and Rosenkranz (2011), Rosato (2016), Piccolo and Pignataro (2018)).⁸ I contribute to this literature by considering a model where the

⁵I assume that price discrimination between online and physical sales are not allowed.

⁶Other important works include Milgrom and Roberts (1982), Pittman (1984), Fudenberg and Tirole (1986), Cabral and Riordan (1997), Farrell and Katz (2005), Creane and Konishi (2009), Fumagalli and Motta (2013).

⁷Other important works on this include Anderson and Renault (2006), Janssen and Shelegia (2015), Lubensky (2017).

⁸Other important works include Che (1996), Kőszegi and Rabin (2006), Anderson and Renault (2009).

uncertainty of the consumer about its valuation of the good is a source of differentiation between retailers. Ultimately, the works that are the most closely related to mine are the ones of Loginova (2009) and Guo and Lai (2017), which study how the presence of an internet retailer affects the location choices of physical stores. I contribute to these works by considering a set-up where consumers are differentiated both in terms of patience and location, such that a switching demand channel is possible. Also, in their works, the online firm is a price-taker, whereas in my model, both firms are profit-maximisers.

The paper is written as follows. In Section 3.2, I develop the general framework of consumer utility I will be using in the rest of the paper. In Section 3.3, I study a one-period model of competition between an online and a physical retailer. In Section 3.4, I develop a two-period version of this model, and describe a theory of predatory investment. In Section 3.5, I investigate the effect of firms' strategies on welfare. In Section 3.6, I perform some robustness checks. In Section 3.7, I conclude.

3.2 General Framework

In this section, I describe the general set-up that I use in the rest of the paper. This framework allows me to study the competition of an online retailer and a physical retailer facing a demand system where consumers may choose to buy a product at a physical shop, directly online, or online after visiting the store.

Let's consider a market in which two types of firms sell a homogeneous good. Firm A is an online retailer, and firm B is a physical retailer.⁹ A and B compete in price and face no marginal costs (for simplicity). In addition, firm A can invest in order to reduce the delivery time experienced by customers buying the product online, and such an investment s is costly. Firm A and B set prices (p_A and p_B) and investment (s) simultaneously and non-cooperatively. There is no information asymmetry, hence the solution concept is the Nash equilibrium.¹⁰

Concerning the demand side of the model, I assume that consumers are perfectly informed about prices and product characteristics as they all have access to the internet prior to the shopping decision. However, the good has experience properties; consumers are uncertain about their valuation θ of the good if they don't "experience" it (e.g. see, smell, touch, try) in a physical retail store.¹¹ Visiting the physical

⁹The reader may find helpful to think of Firm A as "Amazon" and Firm B as "Brick- & -Mortar".

¹⁰Even though there is price competition for a homogeneous product, the standard Bertrand results are not observed in this set-up because the retailers are differentiated in their offer, as it is described in the demand-side of the model.

¹¹This is what Degeratu et al. (2000) call *searchable sensory attributes*.

store has a transportation cost t , which is the opportunity cost of the experience. It represents the willingness to pay for solving the uncertainty about the valuation of the good. Ordering online allows avoiding such a cost, but involves some delivery time: β denotes the discounting related to the waiting time. I assume that returning an online delivery is not possible, or prohibitively costly. For now, online prices are assumed lower than physical prices ($p_A < p_B$) for the sake of model's exposition, even though these prices are endogenous in the model.

From these assumptions, there are three potential consumption patterns (in addition of the no consumption channel). First, some consumers may choose to order the good directly online (the online channel): they don't solve the uncertainty about their valuation and experience some waiting time, but do not pay the transportation cost and benefit from a lower price. Second, some consumers may choose to visit the physical store and buy from it (the local channel): they solve uncertainty and save waiting time, but they pay the transportation cost and a higher retail price. Third, some consumers may choose to visit the physical store and then buy online (the switching channel): they solve uncertainty and benefit from a low price, but they pay transportation cost and experience some waiting time. Table 3.1 summarizes the advantages and disadvantages of each consumption channel.

Channel	Waiting	Experience	Transport	Price Difference
Online	-	-	+	+
Switching	-	+	-	+
Local	+	+	-	-

Table 3.1: Pros and cons of the different consumption channels

Consumers are differentiated according to their patience (β) and their transportation cost (t), which are the parameters determining which consumption channel they will choose (including the no consumption channel). A higher β corresponds to a more patient consumer, and a lower t corresponds to a higher willingness to pay to solve uncertainty. The consumer's valuation for the good θ is unknown *ex ante* and is distributed over $[\underline{\theta}, \bar{\theta}]$ according to a known distribution F , with density function f . This distribution is common knowledge and is the same for all consumers. For the sake of the model exposition, I do not introduce the role of firm A's investment in the utility function yet, but I will later on in this section. Denoting p_A and p_B the retail price of firm A and firm B respectively, the expected utilities of consumer i associated with each consumption channel can be written as follows:¹²

¹²The superscripts o , l , s denote the online, local and switching channel respectively.

$$\begin{aligned}
 E[U_i^o(p_A)] &= \int_{\underline{\theta}}^{\bar{\theta}} (\beta_i \theta - p_A) f(\theta) d\theta \\
 E[U_i^l(p_B)] &= \int_{p_B}^{\bar{\theta}} (\theta - p_B) f(\theta) d\theta - t_i \\
 E[U_i^s(p_A)] &= \int_{\frac{p_A}{\beta_i}}^{\bar{\theta}} (\beta_i \theta - p_A) f(\theta) d\theta - t_i
 \end{aligned} \tag{3.1}$$

I assume that consumers are risk-neutral and behave across two stages, as represented in Figure 3.6. First, they choose whether to order online, visit the physical store or to not consume based on their expected utility. Second, those who chose to visit the physical store resolve their uncertainty about θ and choose whether to order online, buy from firm B or to not consume.¹³

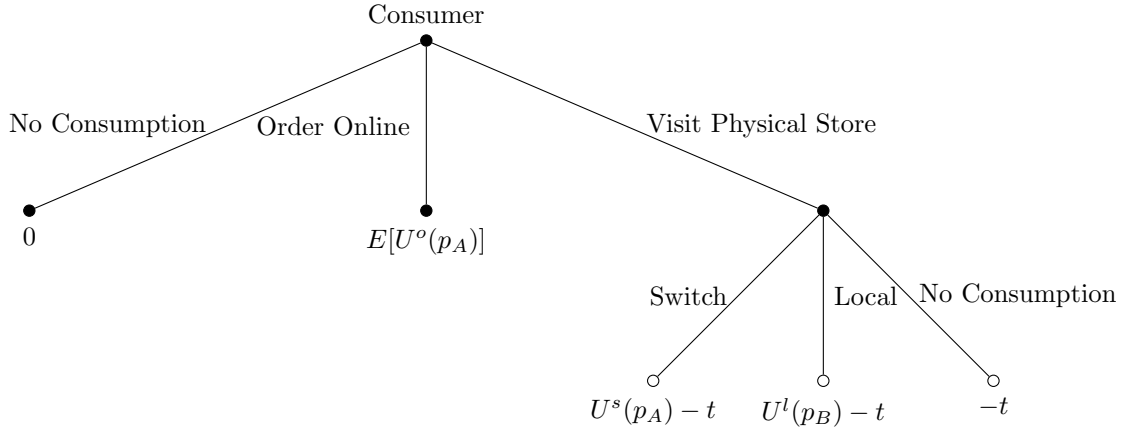


Figure 3.6: Consumer Choice

In the first stage, the consumer will choose to not consume if $\max\{E[U^l], E[U^s], E[U^o]\} < 0$. The consumer will choose to order online if $E[U^o] > \max\{E[U^l], E[U^s], 0\}$. Finally, the consumer will choose to visit the store if $\max\{E[U^l], E[U^s]\} > \max\{E[U^o], 0\}$. Hence, the parameter thresholds that define the consumer's choice in the first stage are the following:

$$\begin{aligned}
 E[U^o] = 0 &\Leftrightarrow \beta_o^*(p_A) = \frac{p_A}{\int_{\underline{\theta}}^{\bar{\theta}} \theta f(\theta) d\theta} \\
 E[U^l] = 0 &\Leftrightarrow t_l^*(p_B) = \int_{p_B}^{\bar{\theta}} (\theta - p_B) f(\theta) d\theta \\
 E[U^s] = 0 &\Leftrightarrow t_s^*(p_A, \beta) = \int_{\frac{p_A}{\beta}}^{\bar{\theta}} (\beta \theta - p_A) f(\theta) d\theta
 \end{aligned} \tag{3.2}$$

¹³ $U^s(p_A)$ and $U^l(p_B)$ denote the second stage utilities net of transportation cost, as described in equation (3.4)

$$\begin{aligned}
 E[U^o] = E[U^s] &\Leftrightarrow t_{os}^*(p_A, \beta) = - \int_{\underline{\theta}}^{\frac{p_A}{\beta}} (\beta\theta - p_A) f(\theta) d\theta \\
 E[U^o] = E[U^l] &\Leftrightarrow t_{ol}^*(p_A, p_B, \beta) = (1 - \beta) \int_{p_B}^{\bar{\theta}} \theta f(\theta) d\theta - \beta \int_{\underline{\theta}}^{p_B} \theta f(\theta) d\theta + p_A - \left(1 - F(p_B)\right) p_B
 \end{aligned} \tag{3.3}$$

These thresholds provide some initial insights. The first threshold determines the level of patience above which the consumer will prefer shopping online rather than not consuming: it increases with the online price and decreases with the expected valuation of the good. The second threshold determines the distance below which the consumer will prefer visiting and buying from the physical shop compared to not consuming: it decreases as the physical price increases. The third threshold determines the distance below which the consumer will prefer to visit the shop and buy online compared to not consuming: it decreases as online price increases and patience decreases. The fourth threshold determines the distance below which a consumer prefers visiting the shop before buying online compared to buying directly online: it increases with the online price. The last threshold determines the distance below which the consumer prefers visiting the physical shop and buy from it compared to buying directly online: it increases as patience decreases, as p_A increases and as p_B decreases. These two last thresholds can simply be interpreted as the moment when the cost of visiting the physical shop equates the cost of not solving uncertainty and waiting for the delivery.

Depending on her observed value of β_i and t_i , the behaviour of the consumer is as follows:

- if $t_i > t_1(p_A, p_B, \beta) \equiv \max\{t_{ol}^*, t_{os}^*\}$ and $\beta_i > \beta_o^*$, she orders online,
- if $t_i < t_2(p_A, p_B, \beta) \equiv \min\{\max\{t_{ol}^*, t_{os}^*\}, \max\{t_l^*, t_s^*\}\}$, she visits the physical store,
- if $t_i > \max\{t_l^*, t_s^*\}$ and $\beta_i < \beta_o^*$, she doesn't consume.

In the second stage, the consumers who visited the store choose between consuming from the physical store, consuming from the online store, and not consuming (hence losing the transportation cost t_i , which was already paid in stage one). The utility functions, net of transportation cost, are as follows:

$$\begin{aligned}
 U^l(p_B) &= \theta - p_B \\
 U^s(p_A) &= \beta_i \theta - p_A
 \end{aligned} \tag{3.4}$$

The consumer will choose to not consume if $\max\{U^l, U^s\} < 0$. The consumer will choose to order online if $U^s > \max\{U^l, 0\}$. Finally, the consumer will choose to buy

from the store if $U^l > \max\{U^s, 0\}$. Hence, the parameter thresholds that define the consumer's choice in the second stage are the following:

$$\begin{aligned} U^l &= 0 \Leftrightarrow \theta_l^*(p_B) = p_B \\ U^s &= 0 \Leftrightarrow \theta_s^*(p_A, \beta) = \frac{p_A}{\beta} \\ U^s &= U^l \Leftrightarrow \theta_{sl}^*(p_A, p_B, \beta) = \frac{p_B - p_A}{1 - \beta} \end{aligned} \quad (3.5)$$

These thresholds show that, after visiting the physical shop, the consumer will consume the good only if its revealed valuation is high enough, and will switch to the online firm only if she is patient enough and if the price difference is large. Depending on her observed value of β and t , the behaviour of the consumer is as follows:

- if $\theta > \theta_1(p_A, p_B, \beta) \equiv \max\{\theta_{sl}^*, \theta_l^*\}$, she consumes at the store,
- if $\theta_s^* < \theta < \theta_{sl}^*$, she orders the good online,
- if $\theta < \min\{\theta_s^*, \theta_l^*\}$, she doesn't consume.

From the firms' perspective, the demand for the good depends on the distribution of β and t . For simplicity, I assume that the distributions of θ , β and t are independent. Assuming that β is distributed over $[0, 1]$ according to a distribution G , with density function g ; and that t is distributed over $[0, \bar{t}]$ according to a distribution H , with density function h , one can derive the demand function for each consumption channel. The demand functions for each consumption channels take the following form:

$$\begin{aligned} D^o(p_A, p_B) &= \int_{\beta_o^*}^1 \int_{t_1}^{\bar{t}} h(t) dt g(\beta) d\beta = \int_{\beta_o^*}^1 (1 - H(t_1)) g(\beta) d\beta \\ D^s(p_A, p_B) &= \int_0^1 \int_0^{t_2} \int_{\theta_s^*}^{\theta_{sl}^*} f(\theta) d\theta h(t) dt g(\beta) d\beta = \int_0^1 (F(\theta_{sl}^*) - F(\theta_s^*)) H(t_2) g(\beta) d\beta \\ D^l(p_A, p_B) &= \int_0^1 \int_0^{t_2} \int_{\theta_1}^{\bar{\theta}} f(\theta) d\theta h(t) dt g(\beta) d\beta = \int_0^1 (1 - F(\theta_1)) H(t_2) g(\beta) d\beta \end{aligned} \quad (3.6)$$

These demand functions have clear interpretations. The online demand channel corresponds to the consumers that are far enough away to prefer online shopping to visiting the shop (i.e. $1 - H(t_1)$ in mathematical terms) and patient enough to prefer consumption (i.e. the integral from β_o^* to 1). In both the local and switching demand, the term $H(t_2)$ represents the portion of consumers that are located close enough to the physical shop to come and visit. If the revealed valuation is high enough, the consumer will choose to consume, and if the price difference between

online and physical retailers is large enough, patient consumers will choose to switch (i.e. $F(\theta_{sl}^*) - F(\theta_s^*)$) and the impatient ones will buy from the shop (i.e. $1 - F(\theta_1)$).

Hence, the pricing strategies of firms concerning the shop visitors will take two aspects: on the one hand, everything else equal, increasing the price reduces the number of visits to the shop, but on the other hand, the visitors revealed their valuation of the good which is potentially very high, meaning that a lot of surplus can be extracted from this “locked” consumer base.

In addition, the online firm can invest to reduce the importance of patience in the utility functions of the consumers. This consists in replacing β_i in equations (3.1) and (3.4) with a function $\mu(\beta, s)$ that is increasing in s and whose maximum value is one. The more firm A invests, the closer to one $\mu(\beta, s)$ is, the less patience will drive consumer’s choice. However, investment is costly, and the cost function $c(s)$ is an increasing and convex function of s .

In the the following two sections, I study two specific variations of the above model. Specifying some distributions over the different parameters of interest (θ , β and t) and some functional form to other functions ($\mu(\beta, s)$ and $c(s)$), I focus on a one-period model of competition in section 3.3 and on a two-period model of competition in section 3.4.

3.3 A One-Period Model of Competition

In this section, the set-up is the following one. I study a duopoly selling an homogeneous good where an online retailer (Firm A) and a physical retailer (Firm B) compete in prices. They produce at no cost. I am exploring a simple discrete model, with the following assumptions. Consumer’s valuation follows a Bernoulli distribution: they have a willingness to pay $\theta = 1$ with an exogenous probability λ , and a willingness to pay $\theta = 0$ with a probability $1 - \lambda$. In this context, λ can be also interpreted as the quality of the good; a higher λ corresponds to a higher probability of “liking” the good. Firm B is exogenously located at 0, in the middle of a segment of length 1, spanning from $[-\frac{1}{2}, \frac{1}{2}]$. Consumers are uniformly distributed along that segment; hence, the parameter t corresponds to their location and is uniformly distributed over the interval $[-\frac{1}{2}, \frac{1}{2}]$. Finally, the patience parameter β is uniformly distributed over the interval $[0, 1]$.¹⁴

Furthermore, concerning firm A’s investment, I assume that $\mu(\beta, s) = \beta + s(1 - \beta)$ and $c(s) = \frac{s^2}{2}$. This specification is such that the online firm can compensate the

¹⁴Uniform distributions are used for simplicity, but triangular distributions are explored in Section 3.6 and Appendix 3.K.

consumer up to a share s of their loss (in utility terms) due to delivery time. Indeed, since the valuation of the good is discounted at rate β due to the waiting time, the waiting costs in utility terms are $(1 - \beta)\lambda$. Hence, with $s \in [0, 1]$, the online firm can invest in delivery services so as to give back a share s of their loss to the consumers. In other terms, it makes impatience “matter less” for all consumers (i.e. across the entire distribution of β). Concerning the cost of investment, I use a standard quadratic form.

The expected utility functions now take the following form:

$$\begin{aligned} E[U^l(p_B)] &= \lambda(1 - p_B) - |t| \\ E[U^o(p_A, s)] &= (\beta + (1 - \beta)s)\lambda - p_A \\ E[U^s(p_A, s)] &= \lambda((\beta + (1 - \beta)s) - p_A) - |t| \end{aligned} \quad (3.7)$$

In first stage of consumer’s behaviour, the consumers choose between buying directly online, visiting the shop, or not consuming depending on their expected utilities (equations (3.7)).

In the second stage, the consumers who visited the store choose between consuming from the physical store, consuming from the online store, and not consuming (hence losing the transportation cost t , which was already paid in stage one). With a probability $(1 - \lambda)$, the consumer has zero willingness to pay for the good; it does not consume and gets a negative utility equal to $-|t|$. With a probability λ , the utility functions, net of transportation cost, are as follows:

$$\begin{aligned} U^l(p_B) &= 1 - p_B \\ U^s(p_A, s) &= \beta + (1 - \beta)s - p_A \end{aligned} \quad (3.8)$$

The thresholds describing consumer’s behaviour are updated below:

$$\begin{aligned} E[U^l] > 0 &\Leftrightarrow |t| < t_l = \lambda(1 - p_B) \\ E[U^o] > 0 &\Leftrightarrow \beta > \beta^o = \frac{p_A - s\lambda}{(1 - s)\lambda} \\ E[U^s] > 0 &\Leftrightarrow |t| < t_s = \lambda(\beta - p_A + s - s\beta) \\ E[U^l] > E[U^o] &\Leftrightarrow |t| < t_{lo} = p_A + \lambda(1 - p_B - \beta - s + s\beta) \\ E[U^o] > E[U^s] &\Leftrightarrow |t| > t_{os} = p_A(1 - \lambda) \\ U^l < U^s &\Leftrightarrow \beta < \beta_{ls} = \frac{1 - p_B + p_A - s}{1 - s} \end{aligned} \quad (3.9)$$

Figure 3.7 displays graphically the three types of demand. For the parameter values

included in the darkest areas, the consumers go directly online. In the blank areas, potential consumers choose to not consume. For the parameter values included in the other areas, the consumers visit the shop. Out of this consumer group, a share λ will choose to consume. For the parameter values included in the lighter grey area, these consumers will buy from the physical shop. In the darker grey area, they will buy online.¹⁵

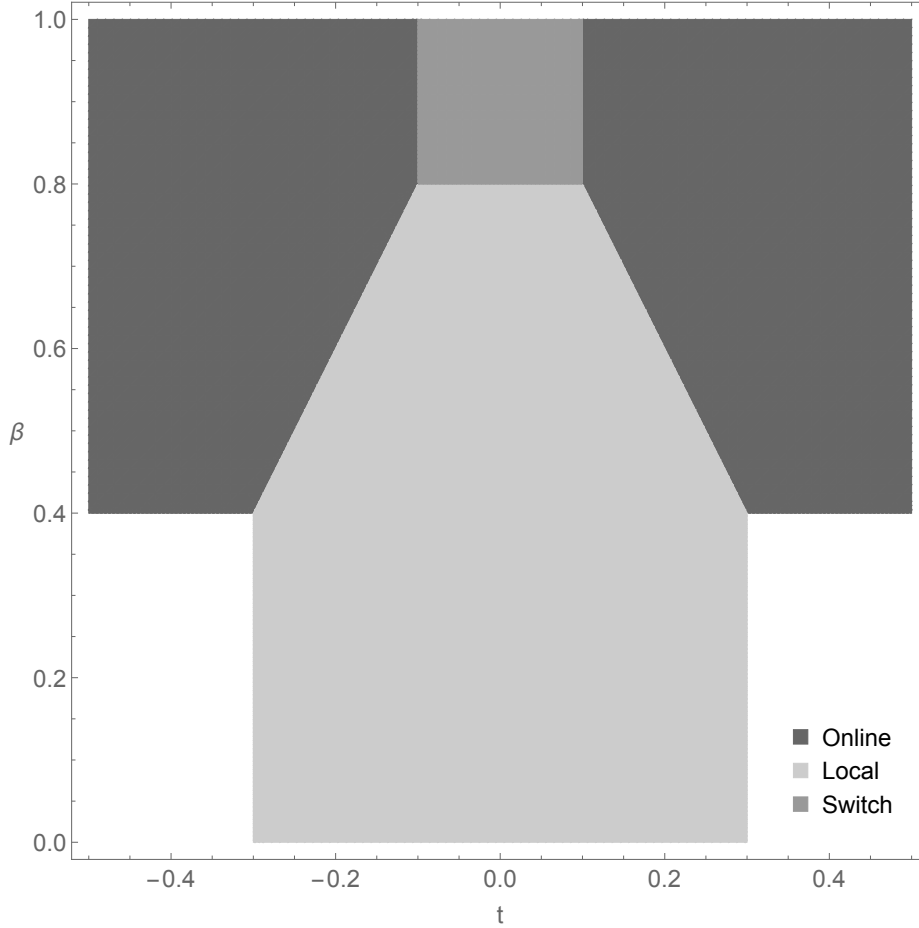


Figure 3.7: Demand representation

Note: The parameterisation is $p_A = 0.2$, $p_B = 0.4$, $s = 0$ and $\lambda = 0.5$.

Hence, defining $t_1(p_A, p_B, \beta) \equiv \max\{t_{ol}, t_{os}\}$ and $t_2(p_A, p_B, \beta) \equiv \min\{\max\{t_{ol}, t_{os}\}, \max\{t_l, t_s\}\}$, the demand functions for each consumption channels take the following form:

$$\begin{aligned}
 D^o(p_A, p_B, s) &= \int_{\beta_o}^1 \left(\int_{-\frac{1}{2}}^{-t_1} dt + \int_{t_1}^{\frac{1}{2}} dt \right) d\beta = 2 \int_{\beta_o}^1 \left(\frac{1}{2} - t_1 \right) d\beta \\
 D^s(p_A, p_B, s) &= \lambda \int_{\beta_{ls}}^1 \int_{-t_2}^{t_2} dt d\beta = 2\lambda \int_{\beta_{ls}}^1 t_2 d\beta \\
 D^l(p_A, p_B, s) &= \lambda \int_0^{\beta_{ls}} \int_{-t_2}^{t_2} dt d\beta = 2\lambda \int_0^{\beta_{ls}} t_2 d\beta
 \end{aligned} \tag{3.10}$$

¹⁵The reader should note that Figure 3.7 does not depend on the distributions of β and t . The parameterisation is chosen for illustrative purposes.

In the following, I study a one-shot game and compare the market outcomes when investments are not possible or possible. Such a comparison allows us to observe the effect of the presence of investments on prices and profits. The timing is as follows: first, companies make their pricing and investment (when possible) decisions simultaneously. Then, consumers decide based on the timing described in Figure 3.6. First, I consider a benchmark model with no investment. Second, I consider the static model with investment.

3.3.1 Benchmark Model - No Investment

In this subsection, the online firm does not have the possibility to invest to reduce waiting costs. In other words, s is exogenous and set at zero. Hence, the retailers just compete in price.

I describe now the firms' profit maximisation problem. The firm's problems are the following ones:

$$\begin{aligned}\max_{p_A} \pi^A(p_A) &= p_A (D^o(p_A, p_B) + D^s(p_A, p_B)) \\ \max_{p_B} \pi^B(p_B) &= p_B D^l(p_A, p_B)\end{aligned}\tag{3.11}$$

These profits functions are continuous but not linear (because t_1 and t_2 are not linear). Indeed, Figure 3.7 can take different shapes depending on pricing strategies. In particular, the following scenarios can happen: if $p_A > \lambda$, the online areas disappear, and the online firm makes sales only through the switching channel. If $p_A > p_B$, the switching area disappears, and the online firm makes sales only through the online channel. If $p_B < p_B^l \equiv \frac{2\lambda-1}{\lambda}$, $t_l = 1/2$, which means the whole location segment is covered by the Firm B (i.e. the blank areas disappear). All these possible shapes will be considered when computing the equilibrium.

Maximising π_B with respect to p_B and maximising π_A with respect to p_A yield closed-form best response functions. The intersection of these best response functions yield the equilibrium prices as a function of λ and does not take a closed-form (but can be solved using a root-finding algorithm).

Proposition 3.1. *In the static model with no investment, there exists a unique solution to the pricing game such that $p_A < p_B$ for all values of λ . When the probability of having a good experience is high enough, the entire market is covered.*

Proof. See Appendix 3.A. □

Figure 3.8 represents equilibrium prices as a function of the probability of having a positive experience from the good, λ .

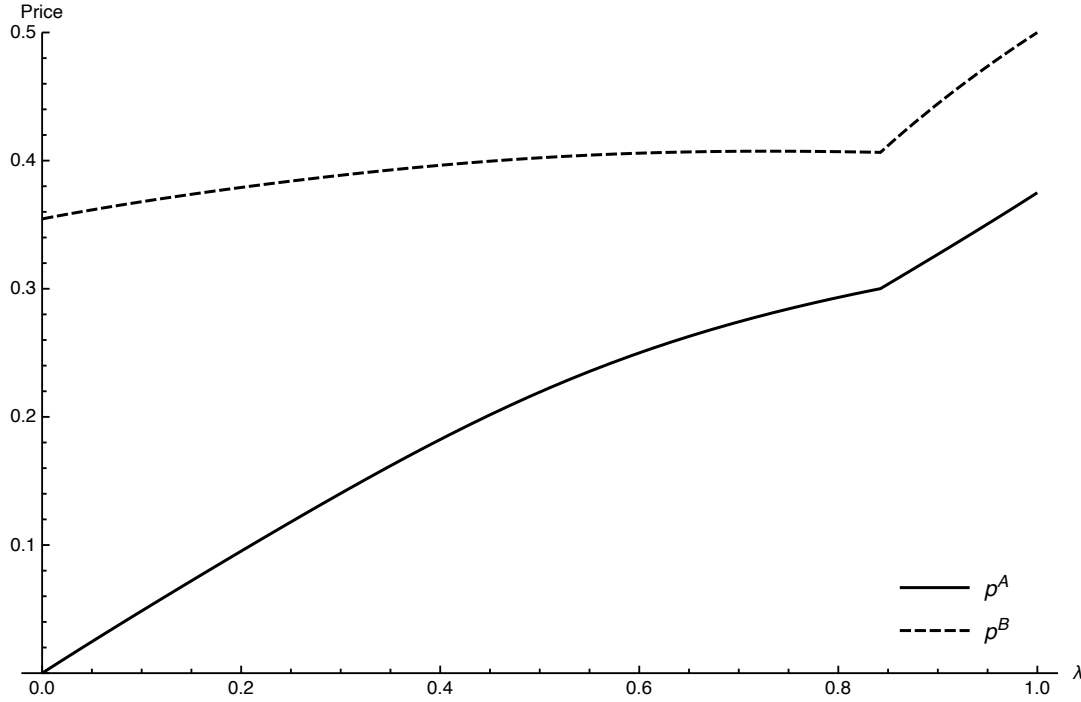


Figure 3.8: Equilibrium prices - Benchmark case

Naturally, price increases as λ increases, since the expected utility consumers are getting from consumption is increasing.

For the online retailer, λ corresponds to the willingness to pay of the online consumers. Since the consumer cannot experience the good, she is willing to pay only up to the expected value of her valuation, which is λ . This is why, as λ approaches zero, p_A approaches zero as well. The online firm could choose to price above λ and serve only the switching channel, but this is never a profitable option for low values of λ , as only a very small share of visitors could potentially be interested in the product.

For the physical retailer, the effect of λ is more ambiguous, due to two opposite forces. On the one hand, λ is independent of the price; taking the number of shop visitors as given, a proportion λ will have a valuation equal to one. These consumers are “captives” with high willingness to pay, which explains why even when λ is very low, firm B chooses to price quite high. On the other hand, decreasing p_B increases the number of visits (i.e. t_l and β_{ls} are decreasing in p_B) and consequently the potential number of “captives”. For higher values of λ , this second incentive is stronger; p_B slightly decreases with λ as firm B is trying to reach more customers.

From $\lambda = \tilde{\lambda} \approx 0.84$, all impatient customers visit the shop (i.e. $t_l = 0.5$): the blank areas from Figure 3.7 collapse and everyone consumes the good. After this point,

the consumer-reaching incentive disappears, and firm B chooses the maximum price it can charge while reaching all customer (which is denoted p_B^l).

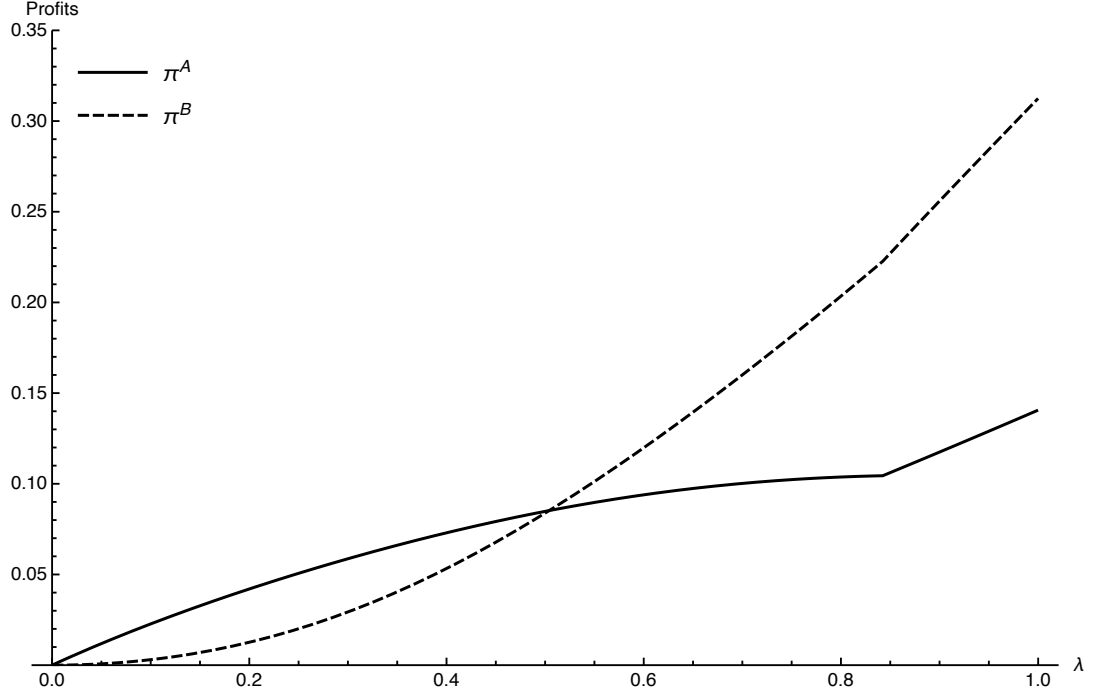


Figure 3.9: Equilibrium profits - Benchmark case

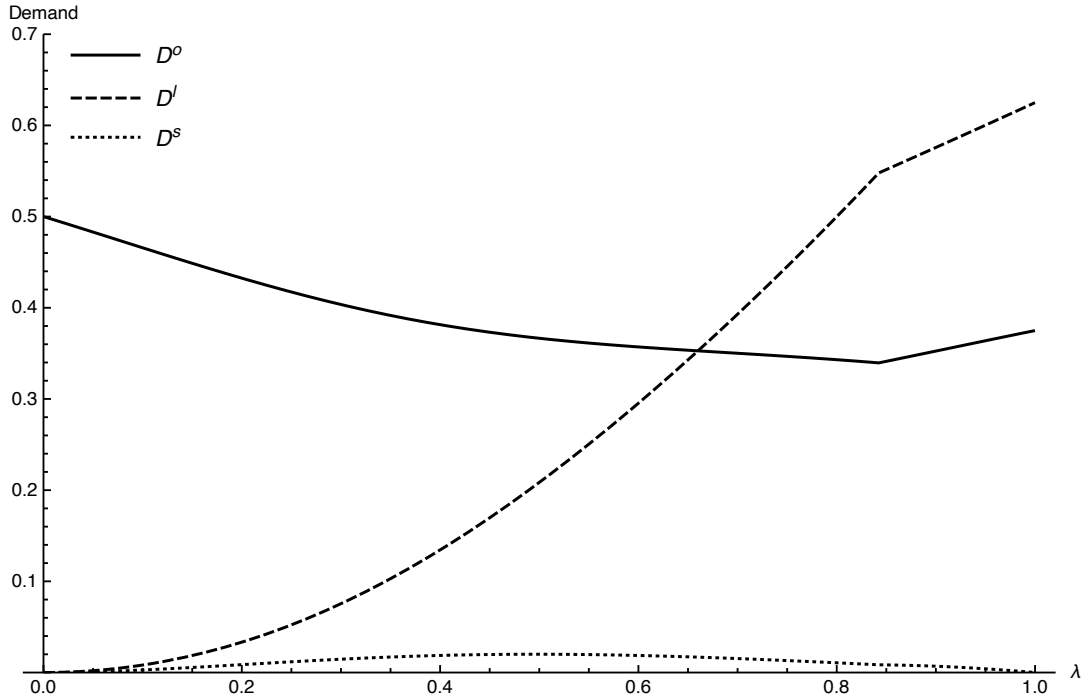


Figure 3.10: Equilibrium demands - Benchmark case

Profits are represented in Figure 3.9. As λ increases, the physical store makes more profits than the online shop. As mentioned above, one can think of λ as the quality of the good, since it represents the probability of having a positive experience. Physical

retailing seems particularly profitable when selling high quality products, whereas online retailers can be profitable both on low quality and high quality products. Hence, this model is consistent with the literature finding that goods of poor quality are generally sold online and those of good quality are generally sold physically (e.g. Huston and Spencer (2002)).

Finally, equilibrium demands are represented in Figure 3.10. This graph shows that the switching segment of demand remains very low and is not an important source of profits for the online firm. Hence, the free-riding channel through which online firms benefit from the sales effort of physical retailers is not very important in this model.

3.3.2 Model with investment

In this subsection, the set-up, timing and assumptions are the same as before, but now, the online firm has the possibility to invest in delivery services. Overall, investment s increases the probability of going online in the first and second stage of the consumer's choice. The firm's problems become:

$$\begin{aligned} \max_{p_A, s} \pi^A(p_A, s) &= p_A(D^o + D^s) - \frac{s^2}{2} \\ \max_{p_B} \pi^B(p_B) &= p_B D^l \end{aligned} \tag{3.12}$$

The presence of investment generates other possible demand shapes. In particular, if $s > \frac{p_A}{\lambda}$, $\beta_o = 0$, which means the online firm serves the entire demand along the patience segment (i.e. the white no consumption areas in Figure 3.7 disappear). All these possible shapes are considered when computing the equilibrium.

I assume that Firm B sets p_B and Firm A sets p_A and s simultaneously. Maximising π_B with respect to p_B and maximising π_A with respect to p_A and s yield closed-form best response functions. The intersection of these best response functions yield the equilibrium prices and investment as a function of λ and does not take a closed-form (but can be solved using a root-finding algorithm).

Proposition 3.2. *In the static model with investment, there exists a unique solution to the pricing game such that $s \leq p_A < p_B$ for all values of λ . When the probability of having a positive experience is high enough, the entire market is covered.*

Proof. See Appendix 3.B. □

The equilibrium prices and investments are depicted in Figure 3.11.

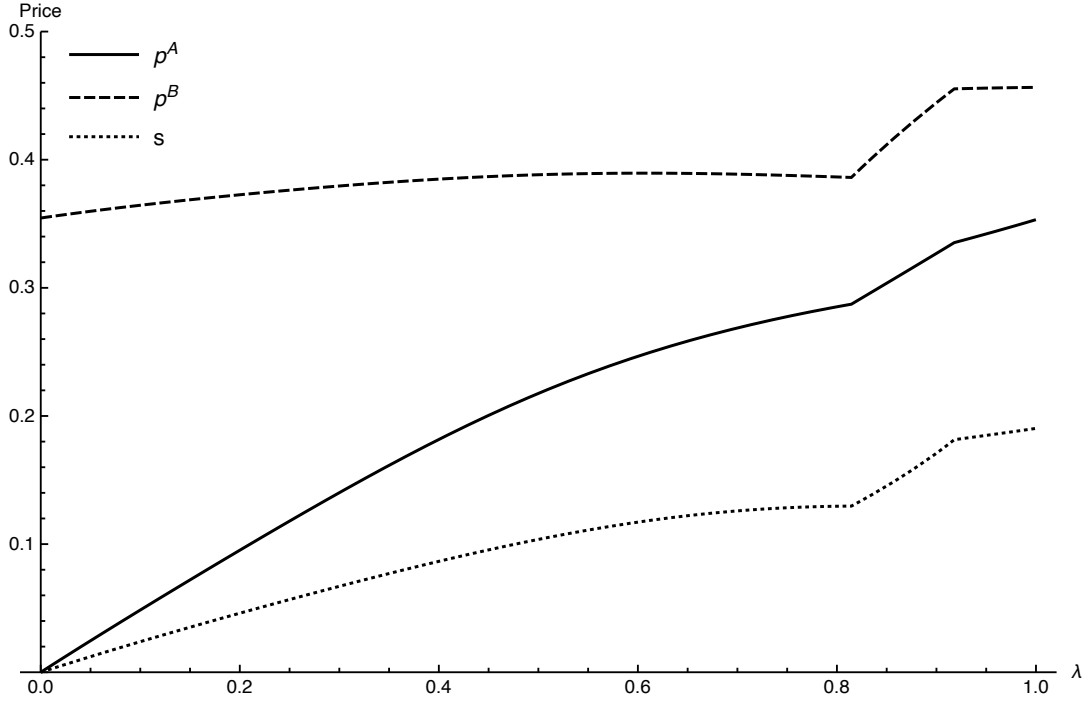


Figure 3.11: Equilibrium prices and investments - Investment case

As before, prices increase with the probability of having a positive experience, and investment follows the same trend.

For the online firm, price is constrained by λ as it corresponds to the maximum willingness to pay of the online consumer. When λ is very low, firm A is forced to price very low. It doesn't have an incentive to invest in that case, since investment in delivery services (partially) solves the impatience issue but not the uncertainty one. As investment is costly, the firm chooses very low levels of investment when λ is low. However, as λ increases, there is high gains from investments. One can write the marginal utility gain from investment as $(1 - \beta)\lambda$. It becomes clear that, as it is more likely that consumers appreciate the good, investing allows to maximise this higher willingness to pay.

For the Brick-&-Mortar, there still is a trade-off between the exploitation of the high valuation of the “captive” consumers and the incentive to attract more consumers to the shop. The first threshold $\lambda^* \approx 0.81$ corresponds to the quality level at which all impatient consumers visit the store; firm B sets its price at the highest level for which it reaches all consumers along the location segment. However, after the second threshold $\lambda^{**} \approx 0.92$, firm B is forced to bring down its price in order to reach extra customers along the impatience segment. This is due to the fact that investment is increasing faster after λ^* , resulting in firm B losing visitors.

Figure 3.12 represents the profits made by the two firms, and Figure 3.13 represents the levels of the three types of demand. In Appendix 3.F, I compare the prices and

profits under the benchmark and with the presence of investment. In these figures, one can see that in the static game, the presence of investment does not affect prices and profits significantly; at most, the presence of investments decreases B's profits by around 17%.

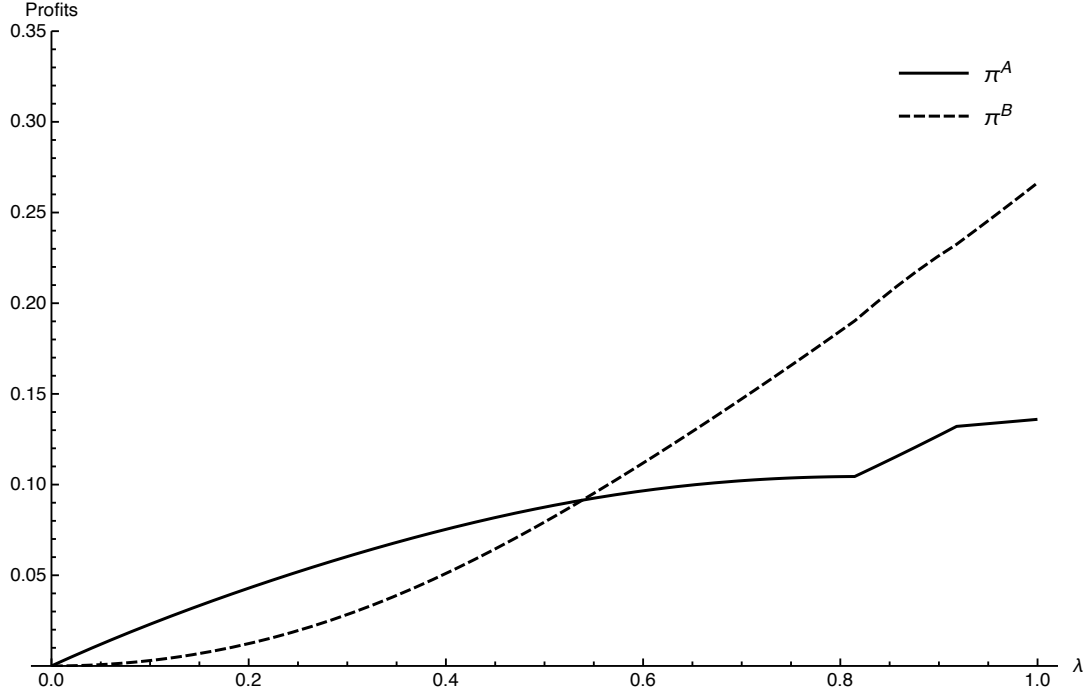


Figure 3.12: Equilibrium profits - Investment case

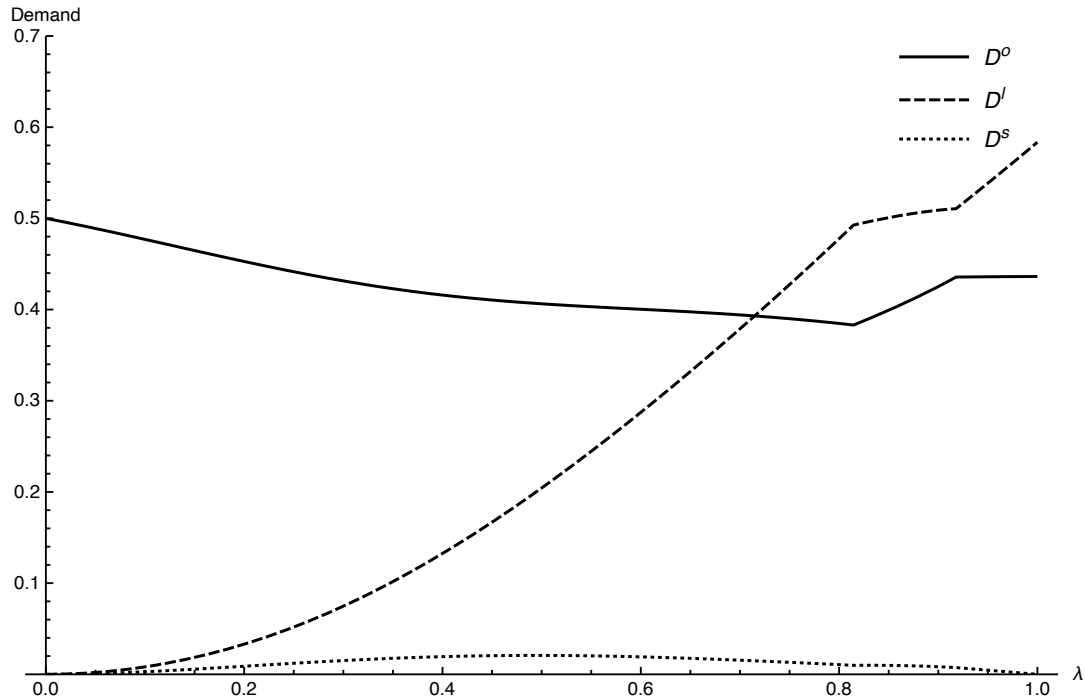


Figure 3.13: Equilibrium demands - Investment case

Remark 3.1. When the online firm has the possibility to invest in delivery services,

it invests relatively low, such that price and profit levels are very close to the ones in the benchmark case. Hence, in static game, the online firm does not have incentives to invest in delivery services to a level that would make the physical firm unprofitable.

3.4 A Two-Period Model of Competition

In this section, I consider a two-period model. The timing is as follows: in the first period, both firms are active. During the second period, the online firm is assumed to be active as well. The physical retailer remains active in the second period if and only if it pays a fixed cost K , which can be interpreted as an investment to remain active during the second period (e.g. rent). If its first period profits are lower or equal to K , Firm B leaves the market at the end of period one. Firms discount time at rate δ .¹⁶

In each period, firms price and invest simultaneously, and the two-stage behaviour of consumers occur. In that context, I investigate three possible strategies of the online firm.

The first strategy is what I call the accommodation strategy. It simply consists in setting the same price and investment level during both periods. The online firm is maximising its per-period profits and set the price and investment level of the one-shot game during both periods.¹⁷ The pricing and investment related to this strategy is described in Section 3.3.2.

The second strategy is what I call the predation strategy without replacement. In period 1, the online firm sets its price and investment so as to make the physical store's profits equal to its fixed cost K . Hence, during this first period, the online maximises its profits under the constraint that the physical firm exists at the end of the period. In period 2, the online firm enjoys monopoly profits and sets monopoly price and investment. It is active online only; the local and switching demand channel are not existing anymore. This strategy is described in Subsection 3.4.1.

The third strategy is what I call the predation strategy with replacement. In period 1, the online firm applies the same pricing and investment strategy than the predation strategy without investment. It excludes its competitor by setting the appropriate price and investment level. In period 2, the online firm sets its own physical retailing facility (i.e. builds one or buys one) and enjoys monopoly profits

¹⁶This discount rate is to be differentiated from the consumer's one β . β can be thought as a within-period discount factor and δ as an between-period discount factor.

¹⁷The physical firm might exit the market depending on its fixed cost K , even though the online firm is not actively trying to provoke such an exit.

over both online and local market. It sets its price and investment level to maximise the sum of its online and physical profits. This strategy is described in Subsection 3.4.2.

Finally, in Subsection 3.4.3, I compare these strategies. In particular, I determine the discount factors for which the online firm finds the predation strategies profitable. Also, I discuss whether the predation strategy with replacement is more profitable than the one without replacement. This allows me to discuss the recent strategies of Amazon, such as the the creation of Amazon 4-star.¹⁸

3.4.1 Predation Strategy without Replacement

In this subsection I describe the predation strategy without replcement. In the following, I set $K = 0.08$, but I explore other fixed costs levels in Appendix 3.I.¹⁹ Prices and investment level are set simultaneously within each period. In this strategy, during the first period, firm A maximises its profits subject to making firm B unprofitable (i.e. $\pi_B = K$). During the second period, firm A maximises its monopoly profits in the online market.

In period 1, the firms' problems are the following ones:

$$\begin{aligned} \max_{p_B} \quad & \pi^B(p_B) = p_B D^l - K \\ \max_{p_A, s} \quad & \pi^A(p_A, s) = p_A (D^o + D^s) - \frac{s^2}{2} \quad s.t. \quad \pi^B(p_B) = 0 \end{aligned} \tag{3.13}$$

I solve firm A's problem using a Langrangian, and firm B's problem using first order conditions. It yields a system of four equations with four unknowns, having a unique solution. The prices and investments are represented in Figure 3.14.

Proposition 3.3. *There exists a fixed cost K for which there is a unique equilibrium to the pricing game such that the online firm exclude the physical firm from the market by decreasing its price and increasing its investments in delivery services.*

Proof. See Appendix 3.C. □

During the exclusion period, the prices and investment are non monotonic in λ . Up to $\lambda \approx 0.5$, we know from Figure 3.12 that the physical store has profits lower than

¹⁸The following results rely on the underlying no re-entry (or irreversible exit) assumption. Many predation models make such an assumption (e.g. Kawakami and Yoshihiro (1997), Wiseman (2017), Argenton (2019)), and in this work, I do not model the presence of barrier to (re)entry. In the conclusion of this chapter, I discuss the reasons why a physical shop would not re-enter.

¹⁹The choice of this specific cost is motivated by the fact it corresponds to the one such that the physical firm can make positive profits for any values above $\lambda = 0.5$.

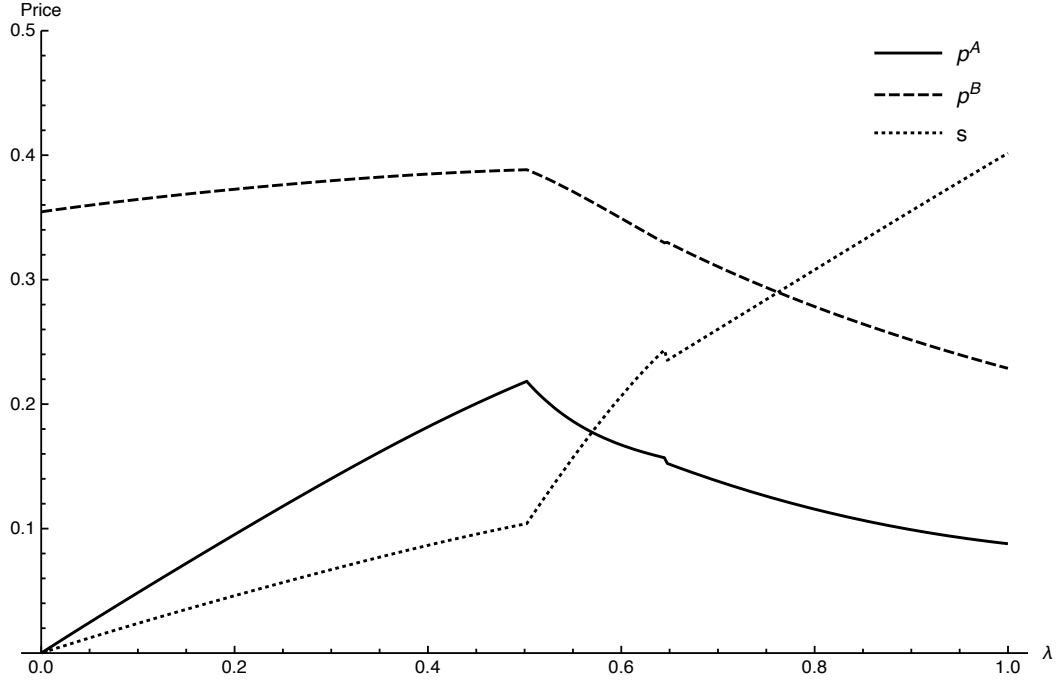


Figure 3.14: Equilibrium prices and investments - Exclusion strategy (period 1)
 Note: The fixed cost K is assumed to be equal to 0.08.

$K = 0.08$ without any predation strategy. Hence, the online store does not invest more than usual for values of λ before this point. Then, from $\lambda \approx 0.5$ on, firm A's strategy consists in simultaneously increase its investment level sharply and decrease its price steadily so as to maintain gross physical profits equal to K . In response, Firm B has to decrease its price to attract enough visitors to the store. From $\lambda \approx 0.64$, firm A is investing enough to reach all consumers along the impatience segment (i.e. $\beta_o = 0$). Firm B is now competing with firm A along the entire β segment, and has to keep decreasing its price to reach enough consumers.

Hence, for the online firm, the most profitable way to exclude a physical competitor is a mix of predatory pricing and aggressive investment.²⁰ In Figure 3.15, one can see that the predation strategy of firm A is particularly costly as λ increases. Figure 3.16 represents each demand channel.

Remark 3.2. *If an online firm aims to exclude its physical competitor, it has to set a very high level of investment in delivery services and experience substantial losses.*

Once the physical store has been driven out of the market, the online firm benefits from a monopoly position during the second period (the so-called “recoupment period”). In the predation without replacement, the online platform operates online only (serving online demand only).

I determine the profit maximising level of prices and investments of the online firm

²⁰Price is predatory in the sense that it is below its static profit-maximising level.

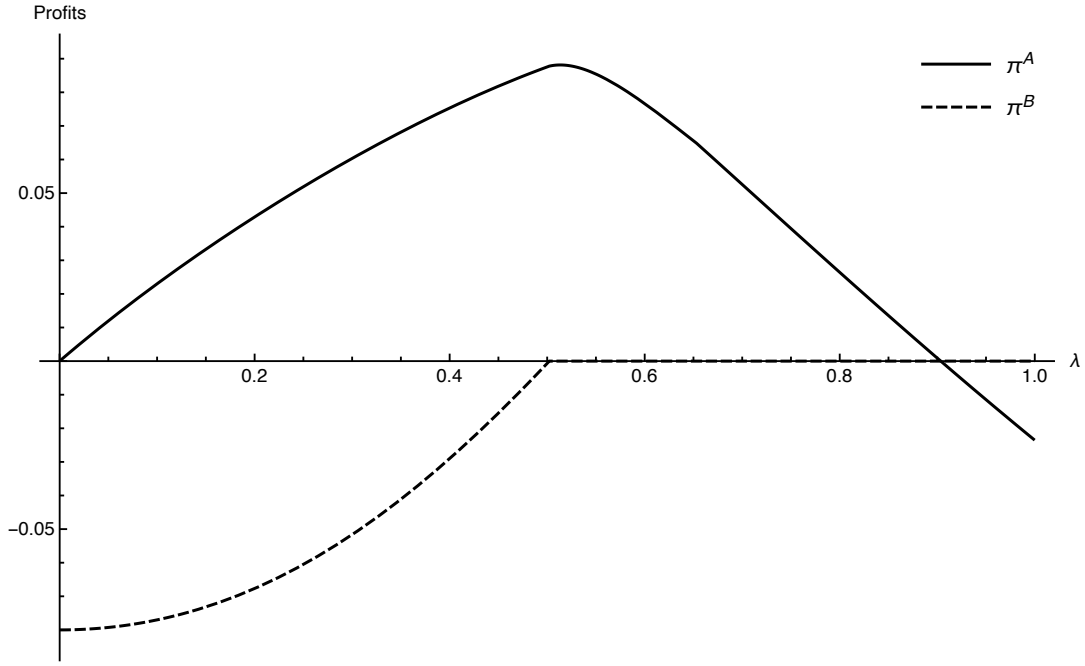


Figure 3.15: Equilibrium profits - Exclusion strategy (period 1)
 Note: The fixed cost K is assumed to be equal to 0.08.

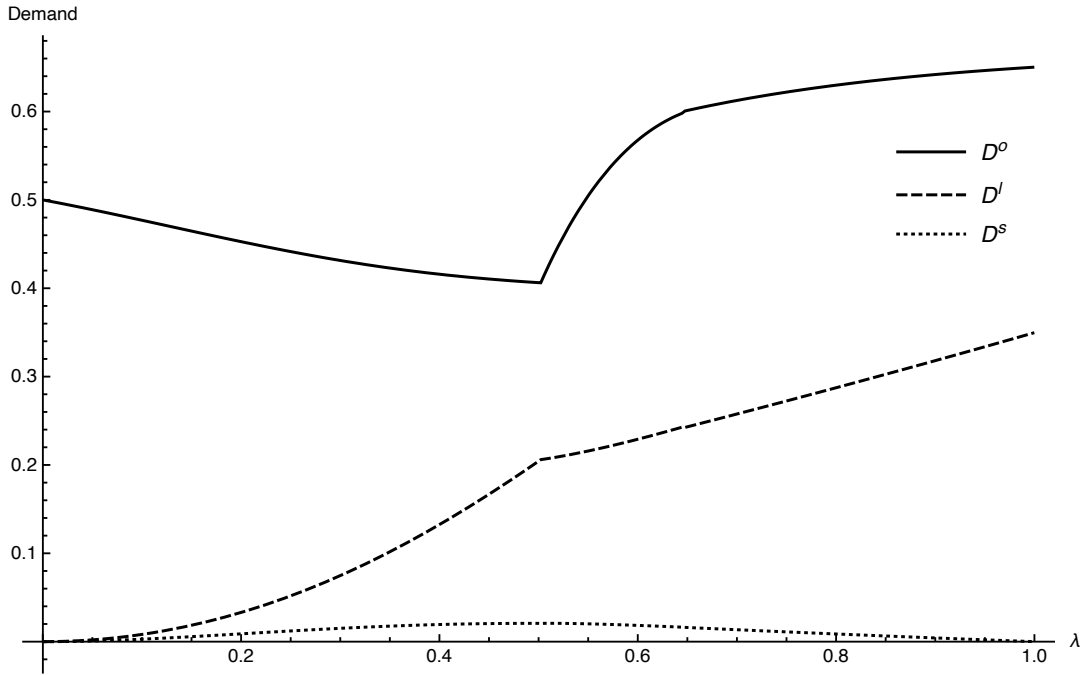


Figure 3.16: Equilibrium demands - Exclusion strategy (period 1)
 Note: The fixed cost K is assumed to be equal to 0.08.

when it is an online monopolist. In equilibrium, two situations may occur: one where the market is partially covered, and one where the entire market is covered.

Proposition 3.4. *During the recoupment period under the no replacement scenario, there exists a threshold $\lambda^* > 0$ such that:*

- for $\lambda < \lambda^*$, the equilibrium price and investment are such that $s < p_A$ and the

market is partially covered,

- for $\lambda > \lambda^*$, the equilibrium price and investment are such that $s > p_A$ and the market is entirely covered.

Both price and investment tend to one as λ approaches one.

Proof. See Appendix 3.D. □

Figure 3.17 represents the level of price and investment under that set-up.

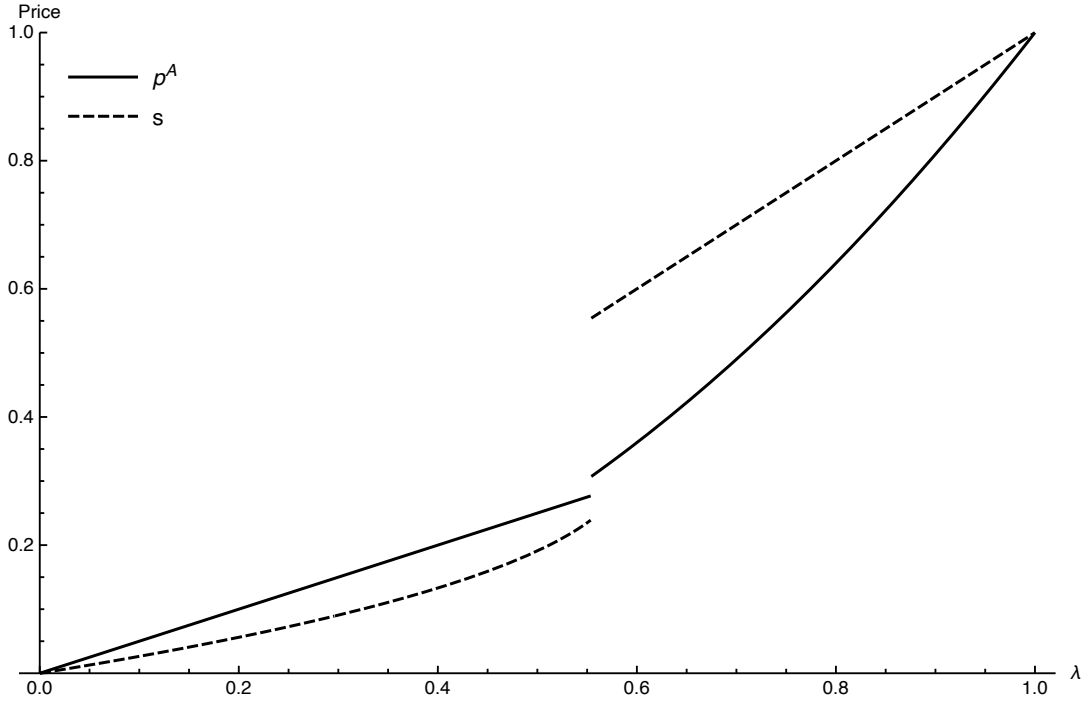


Figure 3.17: Equilibrium price and investment - Recoupment/No Replacement (period 2)

Before the discontinuity, Firm A chooses to serve only patient consumers and to exploit their higher willingness to pay. This is due to the fact the gains from investment are very low at low levels of λ .

After the discontinuity, s is set such that all potential consumers (along the patience segment) are served and p_A is set so as to maximise the profits. When λ is sufficiently large, the gains from investment become sufficiently important to serve the entire market and extract as much surplus as possible from this increased willingness to pay.

Figure 3.18 represents the profits of the online firm under the no replacement scenario, and Figure 3.19 represents the demand faced by Firm A . As mentioned earlier, for lower values of λ , only patient consumers are served, whereas for higher values of λ , all consumers are served.

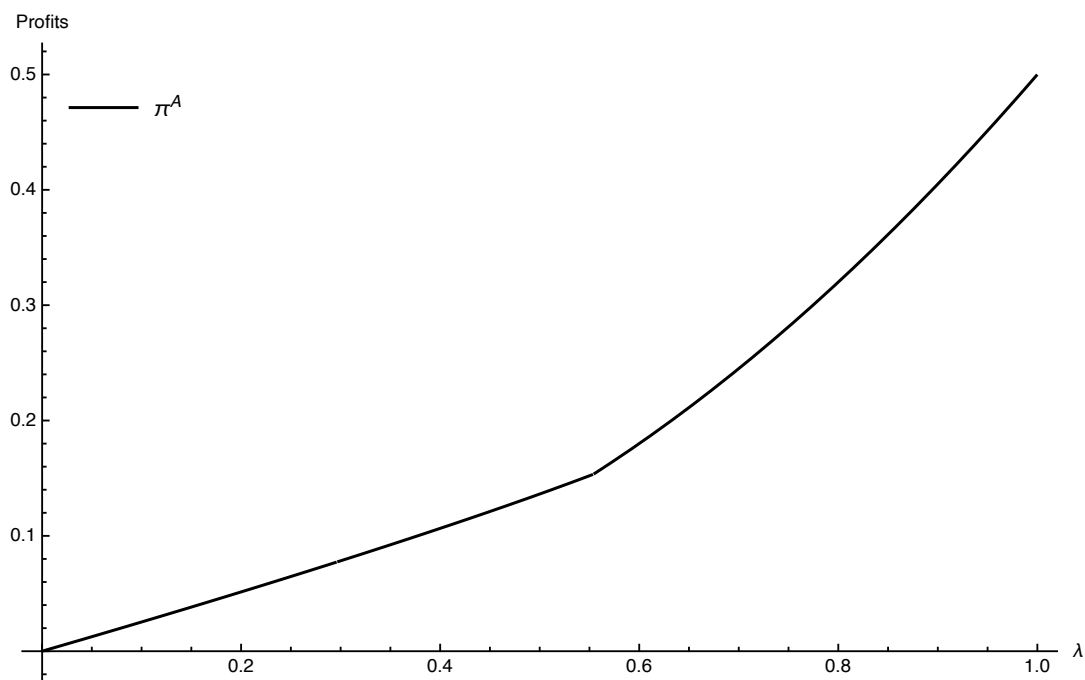


Figure 3.18: Equilibrium profits - Recoupment/No Replacement (period 2)

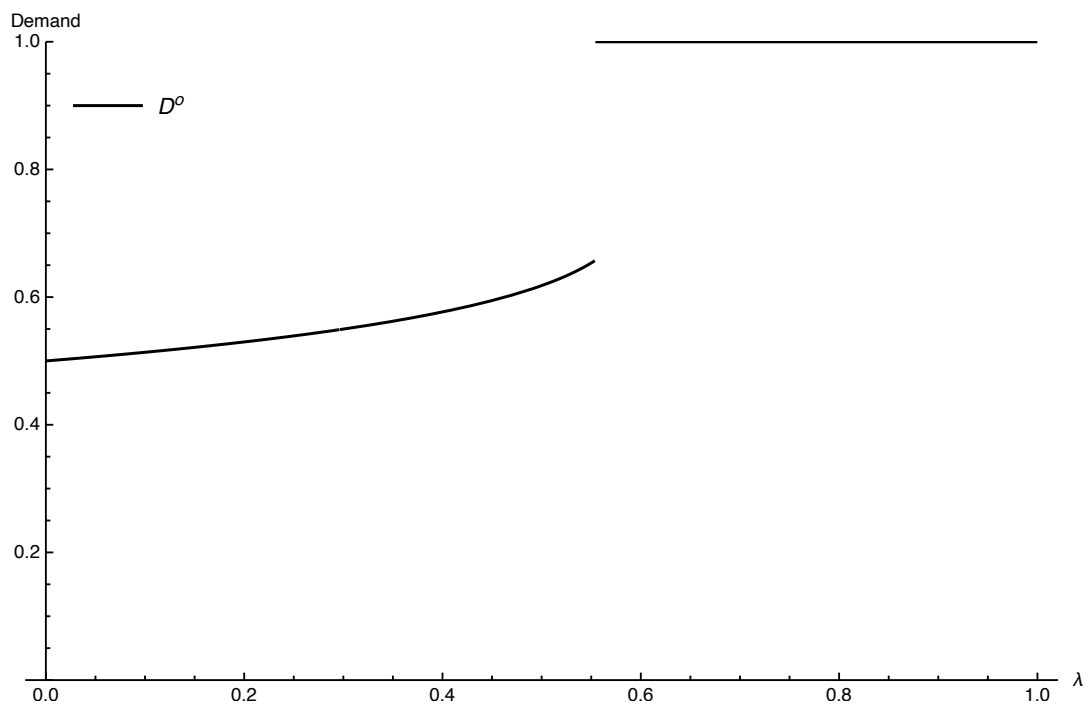


Figure 3.19: Equilibrium demands - Recoupment/No Replacement (period 2)

3.4.2 Predation Strategy with Replacement

In this subsection, I describe the predation strategy with replacement. During the first period, firm A's price and investment are set so that firm B is unprofitable. During the second period, firm A decides to install its own physical store facility (or acquire one) and operates both online and physically (serving online and local

demand). The first period exclusion strategy is already described in the previous subsection (i.e. Proposition 3.3). Hence, I describe only the recoupment period.

In this strategy, after an exclusion phase, the online firm builds (or buys) a physical outlet located in the middle of the segment.²¹ I assume the firm cannot price discriminate (i.e. online price and physical price are the same). Hence, it faces an online demand and a local demand. One may think of this set-up as a physical shop having a website, or as an online platform having some physical retail outlets. This scenario also corresponds to a “predate and merge” strategy, where a dominant firm competes very aggressively so as to acquire the competitor at low cost exploiting a “failing firm defence”. Several situations may arise: the online firm may choose price and investment such that it sells the good only in the physical store, or such that the market is covered along the location segment. All these possible cases are considered when computing the equilibrium.

Proposition 3.5. *During the recoupment period under the replacement scenario, there exists a unique equilibrium to the game such that $p_A \geq s$.*

Proof. See Appendix 3.E. □

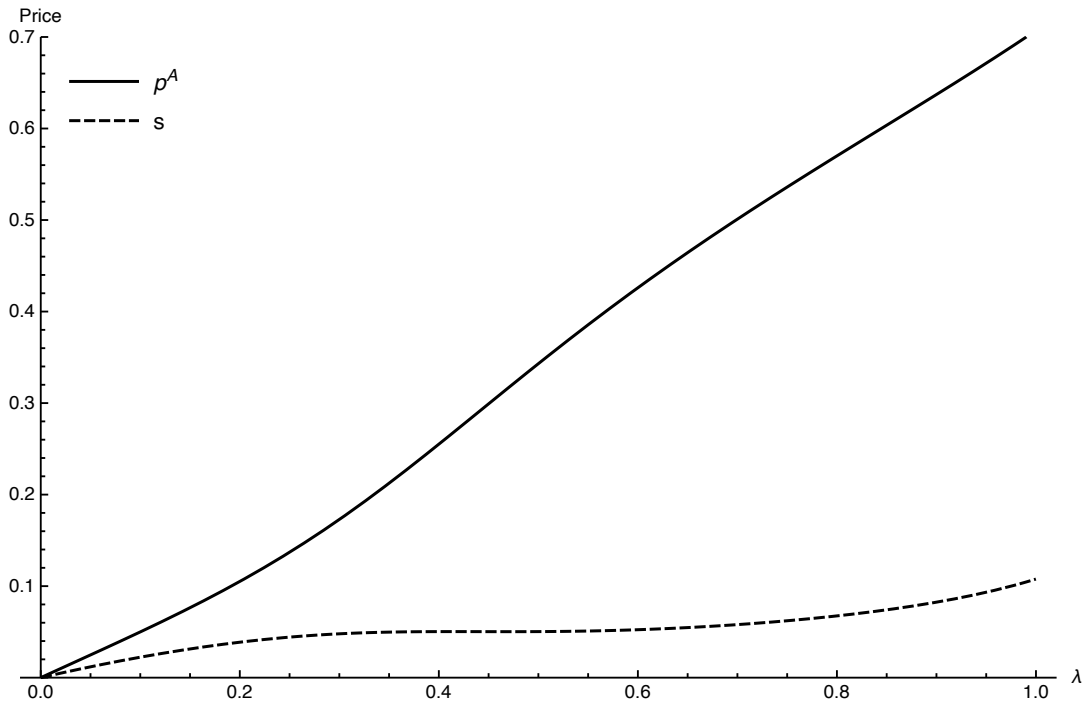


Figure 3.20: Equilibrium price and investment - Recoupment/Replacement (period 2)

Figure 3.20 represents the equilibrium prices and investments that firm A sets in the replacement case. The profit-maximising price is increasing with λ , whereas the

²¹I assume zero replacement cost.

investment remains relatively low as λ increases. Indeed, investing too much would create a “cannibalisation effect” over physical sales, which are the one yielding the highest profits for high quality products. Equilibrium profits are represented in Figure 3.21, and equilibrium demands are represented in Figure 3.22. As λ increases, the online demand decreases, local demand increases and total demand increases.

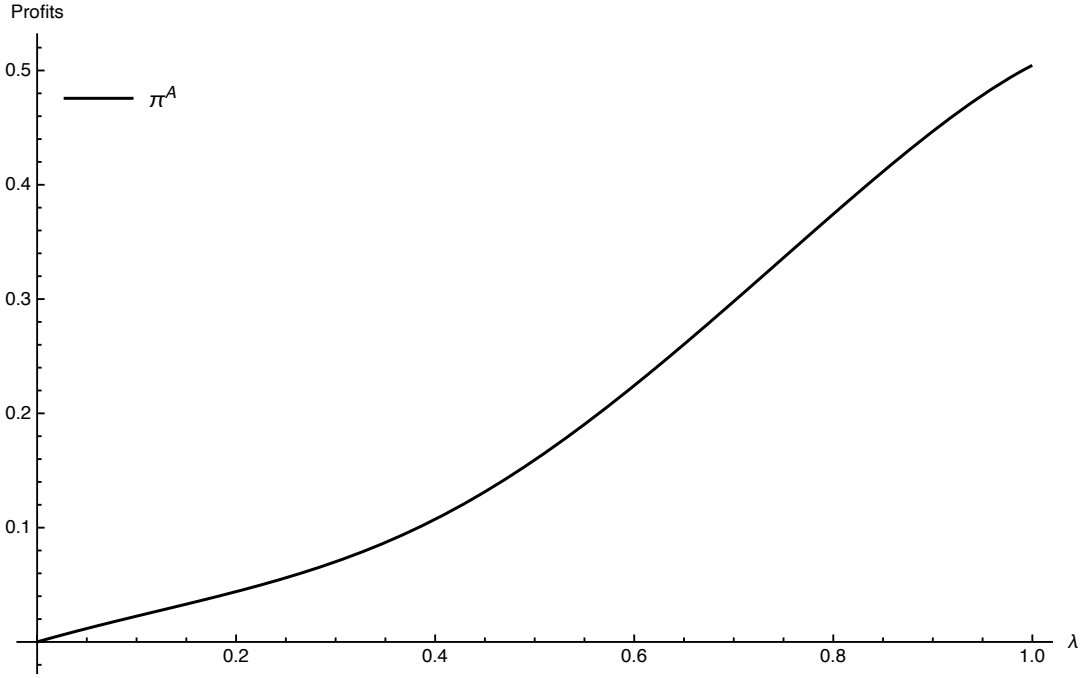


Figure 3.21: Equilibrium profits - Recoupment/Replacement (period 2)

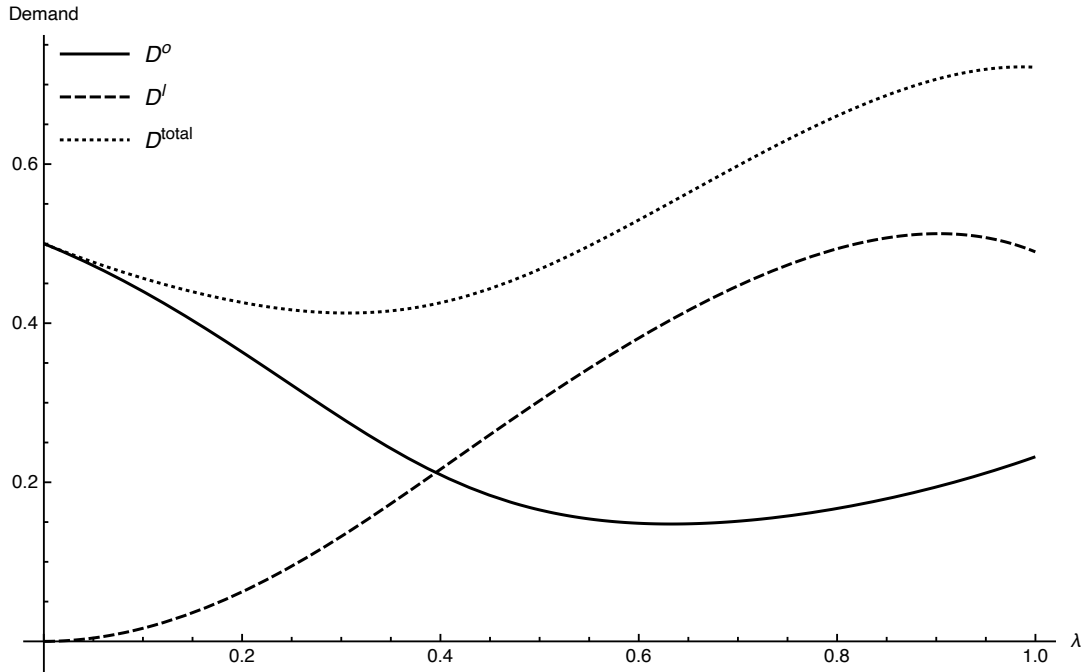


Figure 3.22: Equilibrium demands - Recoupment/Replacement (period 2)

Finally, Figure 3.23 compares the profits under replacement to the ones under no

replacement. One can see that replacement is more profitable for higher values of λ . Hence, an online store should consider building physical outlets only for good quality products. This matches Amazon’s strategy that consisted in building its shops “Amazon 4 star”, which are selling products only with a rating of 4 stars or more.

Remark 3.3. *During the recoupment period, the online firm strictly prefers the replacement strategy when the probability of having a good experience is high enough.*

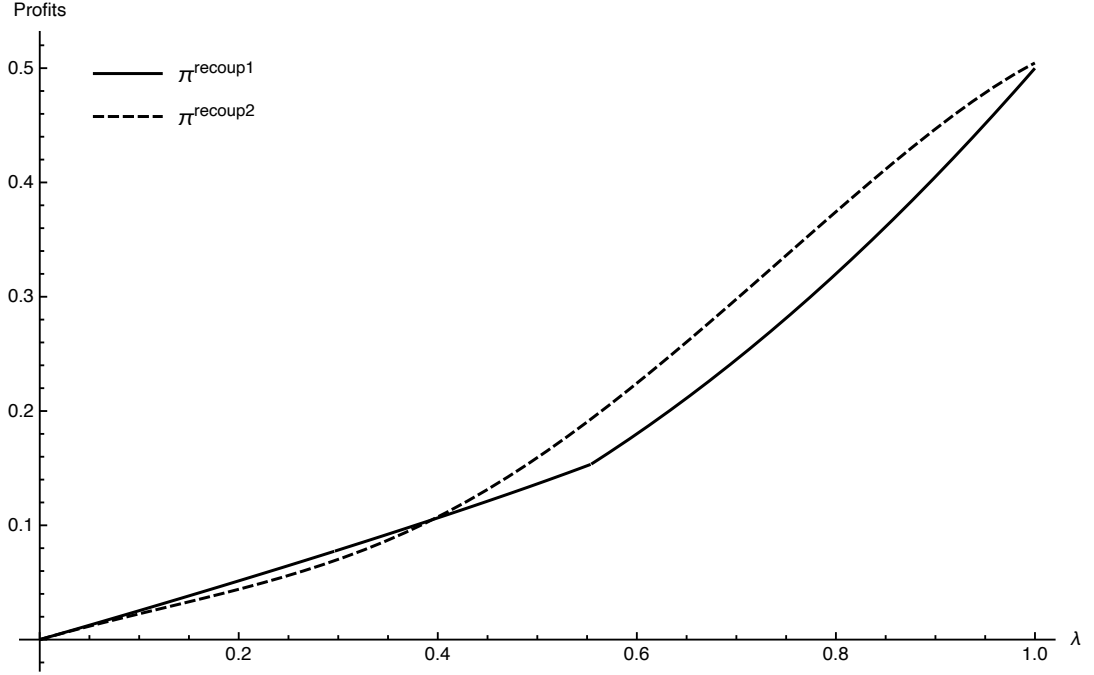


Figure 3.23: Profits comparison - Replacement/No Replacement (period 2)

Note: The plain line, labelled “recoup1”, corresponds to the second period recoupment profits in the predation strategy without replacement. The dashed line, labelled “recoup2”, corresponds to the second period recoupment profits in the predation strategy with replacement.

3.4.3 Profitability of the Predation Strategy

In this subsection, I discuss the profitability of the predation strategy: for which discount factor δ does the online firm engage in a predation strategy? The discounted present value of the online firm’s profits when it does not engage in predation is $\Pi^{\text{accom}} = (1 + \delta)\pi^{\text{accom}}$. When it engages in predation without replacement, the discounted present value of its profits is $\Pi^{\text{pred1}} = \pi^{\text{excl}} + \delta\pi^{\text{recoup1}}$. When it engages in predation without replacement, the discounted present value of its profits is $\Pi^{\text{pred2}} = \pi^{\text{excl}} + \delta\pi^{\text{recoup2}}$. Hence, the recoupment profits (i.e. period 2) can take two forms: one with replacement (“recoup1”), one without replacement (“recoup2”). Figure 3.24 represents all the different streams of profits.

Now, I compute the discount factor for which the online firm is indifferent between

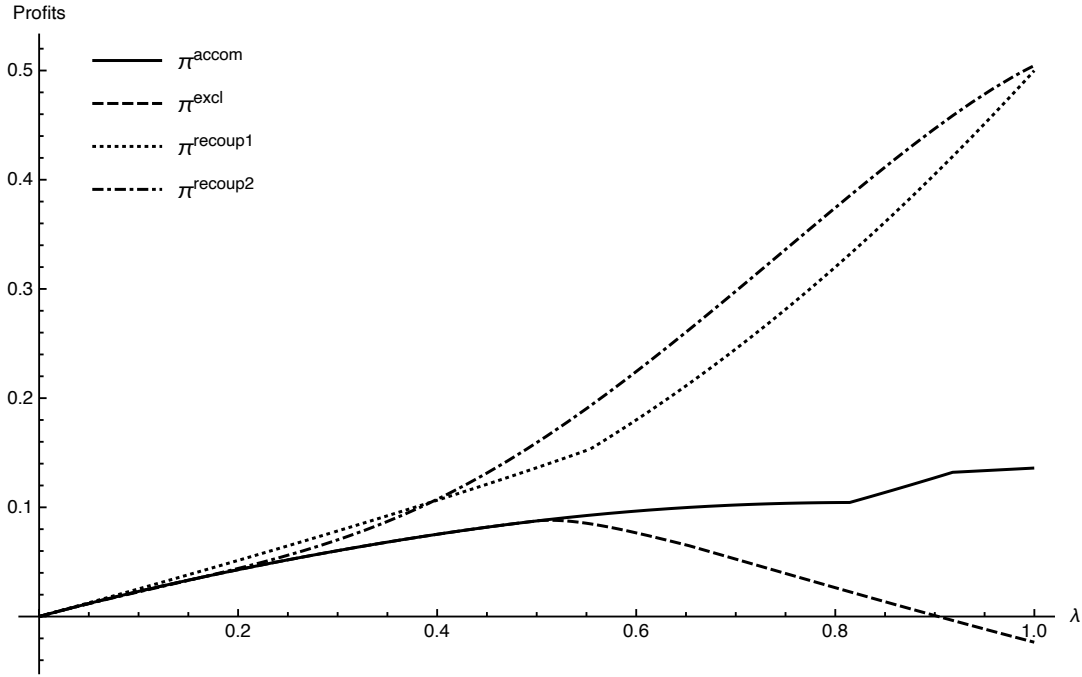


Figure 3.24: Profits comparison

Note: The solid line represents the period 1 and 2 accommodation profits. The dashed line represents the period 1 exclusion profits. The dashed and dotted line represents the period 2 recoupment profits with replacement, assuming zero replacement costs. The dotted line represents the period 2 recoupment profits with no replacement.

predation and accommodation. Depending on the replacement scenario, such a discount factor takes the following form:

$$\begin{aligned}\delta^* &= \frac{\pi^{accom} - \pi^{excl}}{\pi^{recoup1} - \pi^{accom}} \\ \delta^{**} &= \frac{\pi^{accom} - \pi^{excl}}{\pi^{recoup2} - \pi^{accom}}\end{aligned}\tag{3.14}$$

This discount factors are represented in Figure 3.25. The solid line represents the discount factor under no replacement, the dashed line represents the discount factor under replacement. Below the lines, accommodation is more profitable. Above the lines, predation is more profitable. Predation is profitable for a wider range of discount factor when there is replacement during the recoupment period.

Proposition 3.6. *There exists a fixed cost K for which an online firm finds it profitable to exclude its physical competitor whenever it is patient enough. It always prefer to replace the physical store in the recoupment period.*

Proof. This result comes from the prices, investments and profits described in Propositions 3.2, 3.3, 3.4 and 3.5. $\square$

The discount factors are increasing with λ because the physical shop is particularly

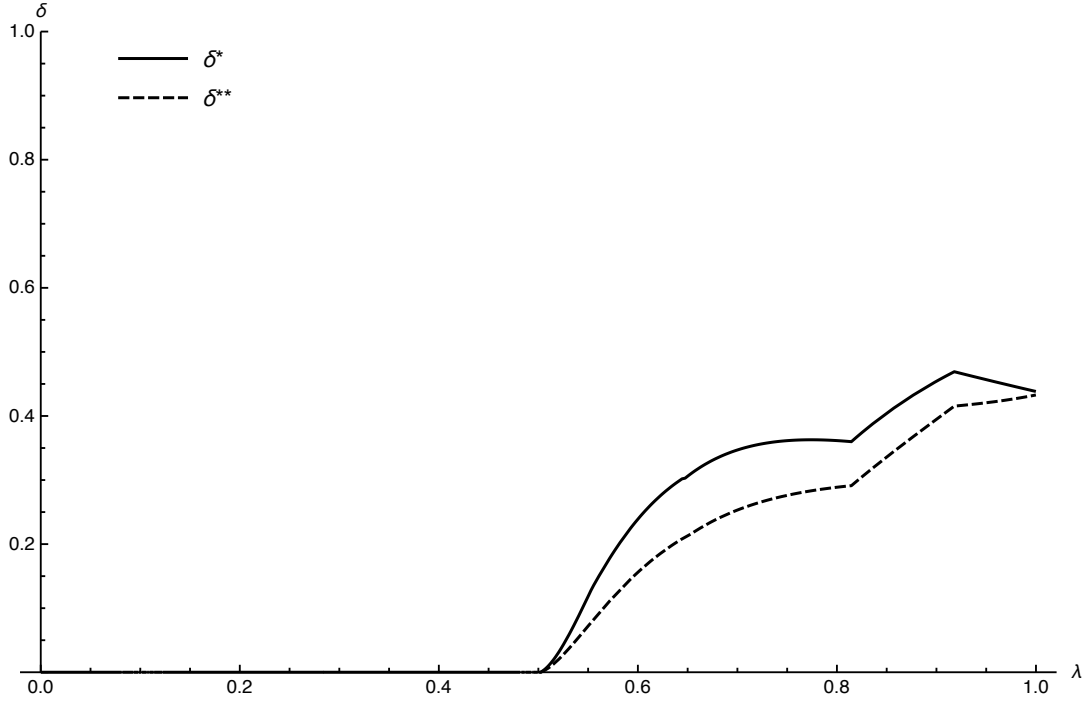


Figure 3.25: Discount Factor

Note: The fixed cost K is assumed to be equal to 0.08. The solid line represents the discount factor above which predation with no replacement is profitable. The dashed line represents the discount factor above which predation with replacement is profitable, assuming zero replacement costs.

profitable when the probability of having a positive experience is high. Hence, the exclusion strategy during period 1 is particularly costly for such values of λ , and it requires more patience from the online firm to find predation profitable.

Hence, this predation model fits many of the facts described in the introduction. On the one hand, Amazon is a particularly forward looking company; it experienced low profitability over the years and high delivery costs more recently, and has installed physical retailers since 2018. On the other hand, physical retailers are experiencing low profits and many of them are closing down since 2017.²²

As a robustness check (discussed in section 3.6), I explore another distribution along the location segment, and I show that when the physical shop is located at the most densely populated point, the online firm finds predation profitable mainly when replacement is possible. This also explains why Amazon launched its physical retail outlets in the most densely populated areas of the USA (e.g. Manhattan). In the following section, I describe the effect of the firms' strategies on consumer's surplus.

²²Of course, the above results rely on the underlying no re-entry (or irreversible exit) assumption.

3.5 Welfare Analysis

In this section, I discuss the impact of firms' strategies on welfare. First, I define the expected consumer surplus over the β and t segment. The expected surplus of the online, switching and local customers are defined by equations (3.15).

$$\begin{aligned} CS^o(p_A, p_B, s) &= 2 \int_{\beta_o}^1 \int_{t_1}^{1/2} E[U^o(p_A, s)] dt d\beta \\ CS^s(p_A, p_B, s) &= 2 \int_{\beta_{ls}}^1 \int_0^{t_2} E[U^o(p_A, s)] dt d\beta \\ CS^l(p_A, p_B, s) &= 2 \int_0^{\beta_{ls}} \int_0^{t_2} E[U^l(p_B)] dt d\beta \end{aligned} \tag{3.15}$$

This section proceeds as follows. First, I describe the consumer surplus in the one-period model. Following this, I describe the consumer surplus in the two-period model. Then, I describe for which discount factors the consumers prefer predation to accommodation. Finally, I describe for which discount factors the society (i.e. consumers, physical and online retailers) prefers predation to accommodation.

3.5.1 Welfare in the One-Period Model

In this section, I describe the consumers' surplus in the one-period model. First, I describe the benchmark case. I then discuss the model with investment.

3.5.1.1 Benchmark Case

The consumer surplus of the different consumer types is represented in Figure 3.26.

Overall, the total consumer surplus increases with λ . As λ increases, more consumers are served (along the impatience segment and along the location segment), and those who were already served have a higher willingness to pay.

Concerning the online segment, consumer surplus increases solely because of the increase in willingness to pay, which is $\beta\lambda$. Indeed, as Figure 3.10 shows, online demand does not increase in λ . The online price grows slower than λ , explaining why the consumer surplus increases.

The local consumer surplus increases mainly because demand increases as λ increases; more consumers visit the shops, and out of these visitors, a larger share will have a positive experience and buy the good. However, their willingness to pay remains unaffected, and the physical price remains relatively stable for most parameter values. Furthermore, once $\lambda > \tilde{\lambda}$, the number of visitors no longer increases,

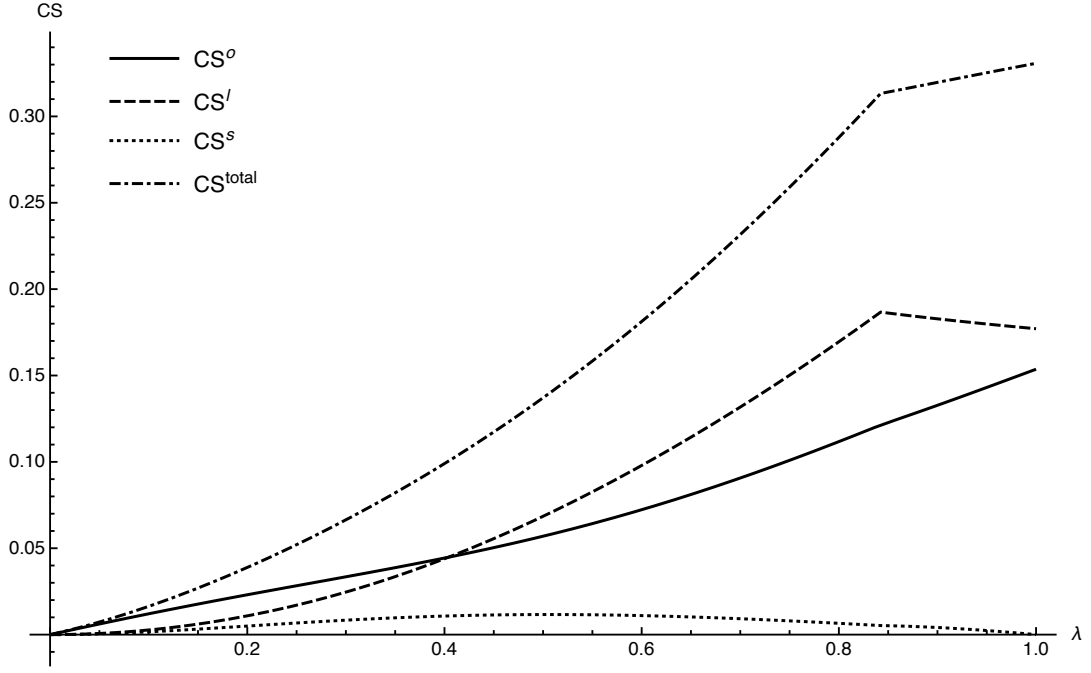


Figure 3.26: Consumer Surplus - Benchmark case

and the price charged by the physical store significantly increases, explaining why local consumer surplus decreases with λ beyond $\tilde{\lambda}$.

The switching customers' surplus is increasing first, then decreasing in λ . This reflects the shape of the switching demand curve in Figure 3.10. When λ increases, the probability of switchers to buy the good increases, but the gap between online and physical prices decreases. Hence, the switching consumers' surplus (and demand) remains low.

3.5.1.2 Model with Investment

In this section, I describe the consumer surplus in the one-period model with investment. The online, local and switching consumer surplus in the absence of predation are represented in Figure 3.27.

In this case, the total consumer surplus also increases with λ .

The online consumer surplus has the same shape as in the benchmark case but it is overall higher. This is due to the investment in delivery services, which increases the willingness to pay of online consumers since they receive the product faster. The online price being similar to the benchmark one, the consumer surplus is overall higher in the presence of investment. The same holds for the switching consumers.

The mechanism underlying the shape of the local consumer surplus is the same as the benchmark case. First, increasing λ increases the number of visitors and the likelihood of them buying the good. Once it reaches, say, λ^* , the number of visitors

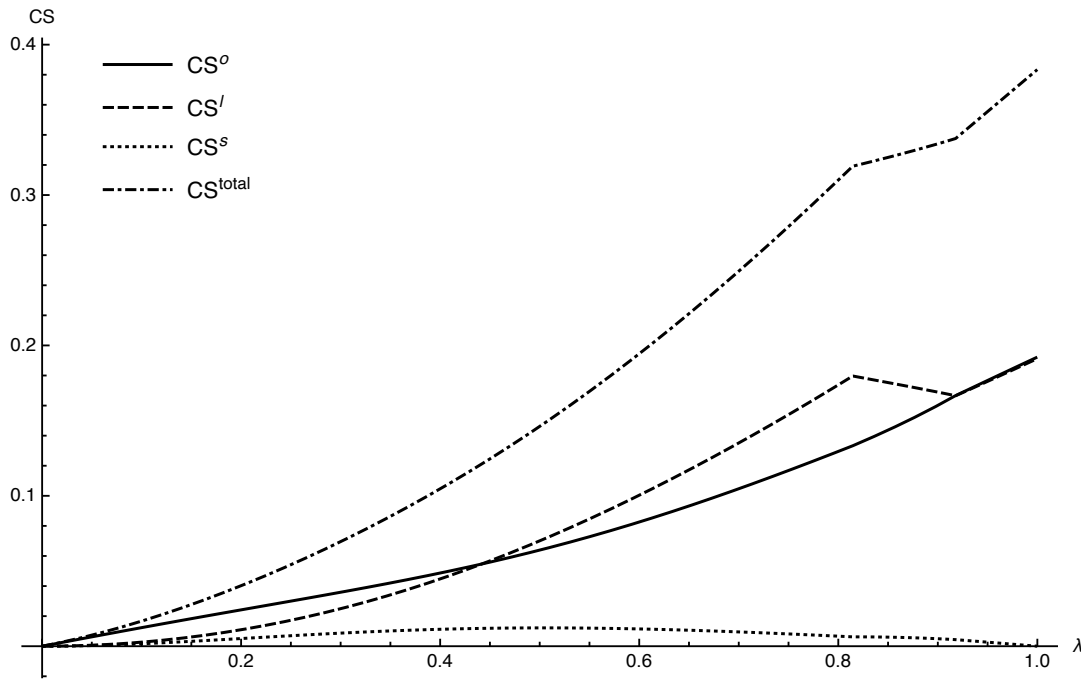


Figure 3.27: Consumer Surplus - Model with Investment

no longer increases, and the price rises, which cause the surplus to decrease. After, say, λ^{**} , the physical price stops rising, making the consumer surplus increase again.

3.5.2 Welfare in the Two-Period Model

In this subsection, I describe the consumers' surplus in the two-period model. The per-period consumers' surplus under the accommodation strategy is already described in subsection 3.5.1.2. Hence, I will describe the consumers' surplus under the predation strategy without replacement first, and then I will explore the consumer's surplus under the predation strategy with replacement.

3.5.2.1 Predation Strategy without Replacement

In this section, the consumers' surplus under the predation strategy without replacement is described. The online, local and switching expected consumer surplus during the exclusion period (i.e. period 1) are represented in Figure 3.28.

Overall, total consumer surplus increases with λ . Exclusion increases the total surplus as investments in delivery services are very high, and prices are lower than in absence of predatory intent.

Before $\lambda \approx 0.5$, consumer surplus is identical to the accommodation case as the online firm did not exert any efforts yet in order to exclude firm B, as B does not make enough profits to pay the fixed cost K . For higher values of λ , firm A invests aggressively and decreases its price, which causes firm B's price to decrease as well

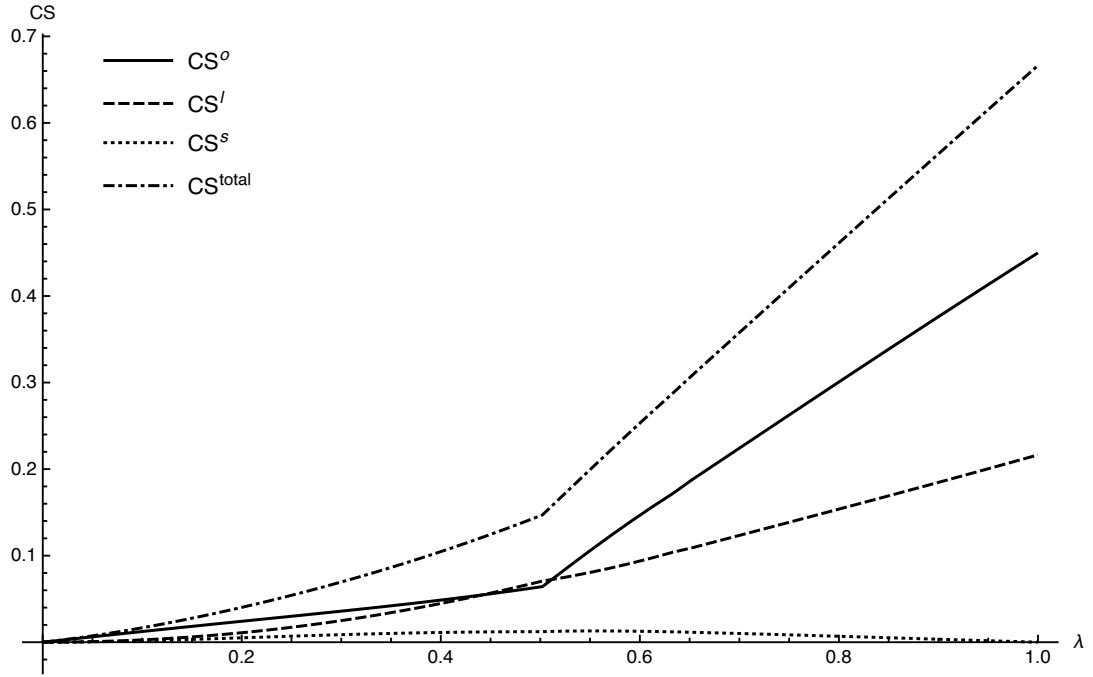


Figure 3.28: Consumer Surplus - Exclusion period (period 1)

Note: Physical retailer's fixed cost is assumed to be equal to 0.08.

and consumer surplus to increase.

Once the physical competitor is excluded, the online consumer surplus during the recoupment period (i.e. period 2) is represented in Figure 3.29 (without replacement).

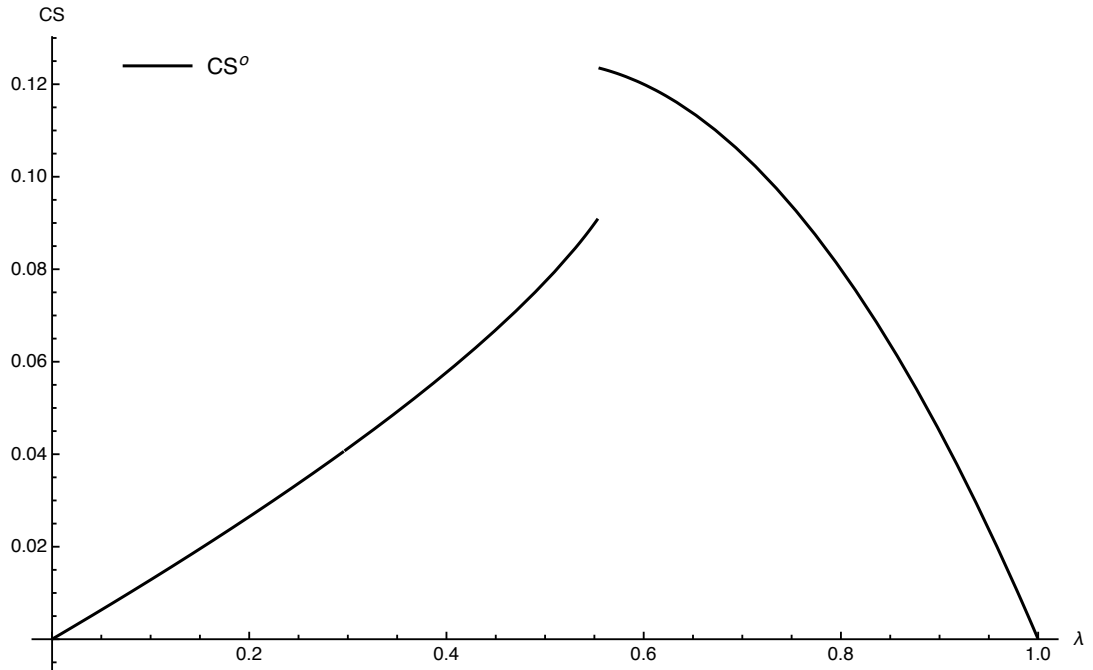


Figure 3.29: Consumer Surplus - Recoupment with no Replacement (period 2)

Without replacement, online consumer surplus increases first with λ . Indeed, for low

values of λ , only patient consumers are served, and as λ increases, their willingness to pay increases and is increasing even more as investment in delivery services increases as well. After the discontinuity, the online firm chooses to invest just enough to serve the entire market, and sets its price at the monopoly level. Just after the discontinuity, consumer surplus increases since much more consumers are served and the price did not increase too much at this stage. As λ increases, price keeps increasing and consumer surplus decreases until reaching zero.

3.5.2.2 Predation Strategy with Replacement

Under the predation strategy with replacement, the consumers' surplus during the exclusion period is the same than the one under the predation strategy without replacement. Hence, in this section, I describe only the consumers' surplus only during the recoupment period with replacement (i.e. period 2), represented in Figure 3.30.

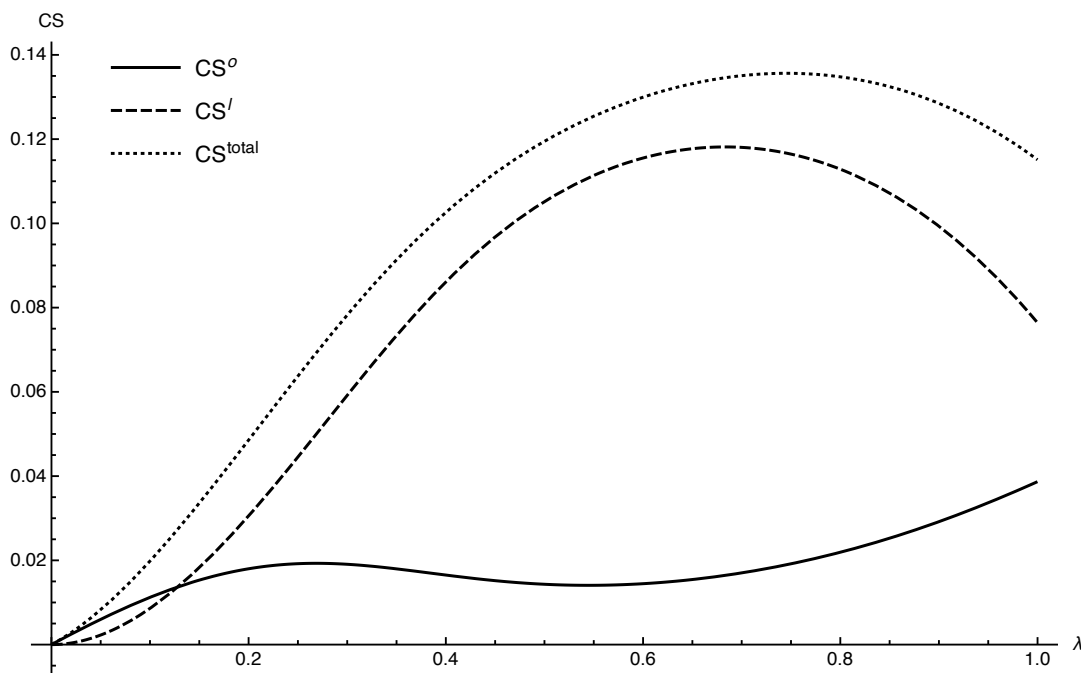


Figure 3.30: Consumer Surplus - Recoupment with Replacement

With replacement, the online consumer surplus remains relatively low, as Firm A chooses to not invest a lot and to increase its price with λ . This is to extract as much surplus as possible from the growing base of local consumers. This is also why the local consumer surplus starts decreasing for high values of λ ; the increasing number of visits (and probability of purchase) does not offset the reduced surplus from the price increase.

It is important to note that during the recoupment period, the total consumer surplus is always higher with replacement compared to no replacement. Everything

else equal, the presence of a physical store allows the consumers located close-by to experience and purchase the good without waiting time.

3.5.3 Do Consumers like Predation?

In this section, I discuss the effect of the predation strategy on the consumers: for which discount factor δ do consumers prefer predation to accommodation?²³ The discounted present value of the expected consumer surplus under the accommodation strategy is $\Omega^{accom} = (1 + \delta)CS^{accom}$. Under the predation strategy without replacement, the discounted present value of the expected consumer surplus is $\Omega^{pred1} = CS^{excl} + \delta CS^{recoup1}$. Under the predation strategy with replacement, the discounted present value of the expected consumer surplus is $\Omega^{pred2} = CS^{excl} + \delta CS^{recoup2}$. Hence, the consumers' surplus during the recoupment period (i.e. period 2) can take two forms: one with replacement, one without replacement. Figure 3.31 represents all the different streams of consumer surplus.

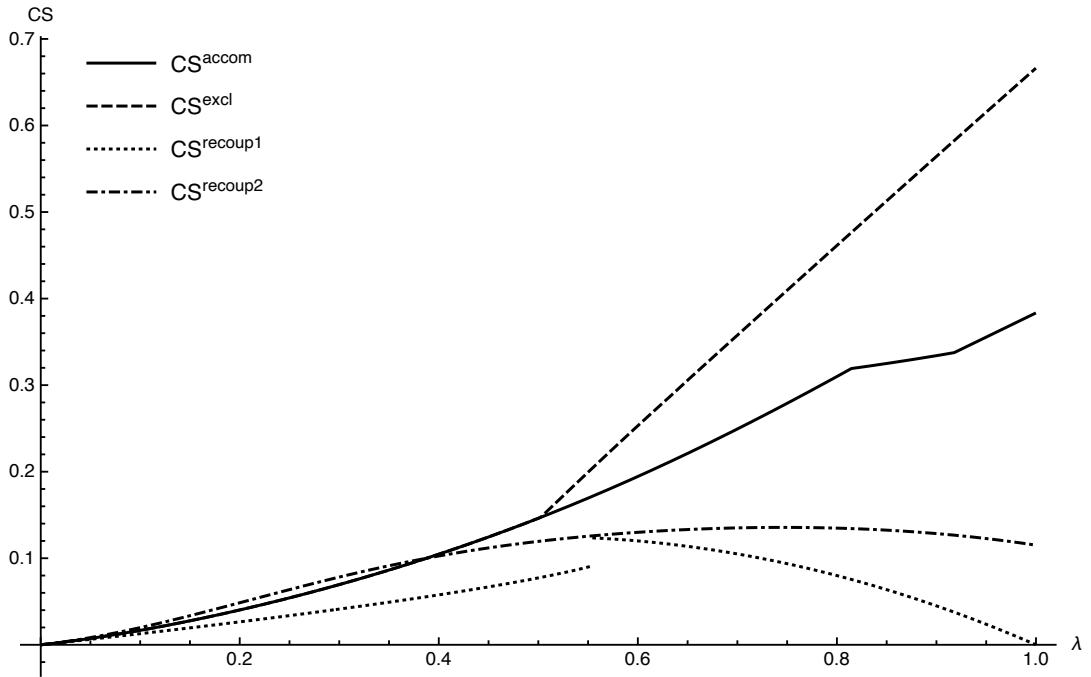


Figure 3.31: Consumer Surplus comparison

Note: The solid line represents the accommodation consumer surplus. The dashed line represents the exclusion consumer surplus when $K = 0.8$. The dashed and dotted line represents the consumer surplus with replacement. The dotted line represents the consumer surplus with no replacement.

Now, I compute the discount factor for which the consumers are indifferent between predation and accommodation. Depending on the type of recoupment, such a discount factor can take the two following forms:

²³This long-term discount factor is to be differentiated from the waiting time related discount factor β . β corresponds to the discounting related to waiting a few days or weeks, whereas δ is the discounting associated with payoffs obtained in a few months or years compared to those obtained today.

$$\begin{aligned}\delta' &= \frac{CS_{accom} - CS_{excl}}{CS_{recoup1} - CS_{accom}} \\ \delta'' &= \frac{CS_{accom} - CS_{excl}}{CS_{recoup2} - CS_{accom}}\end{aligned}\tag{3.16}$$

These discount factors are represented in Figure 3.32. The solid line represents the discount factor under no replacement, the dashed line represents the discount factor under replacement. Below the lines, predation is preferred. Above the lines, accommodation is preferred.

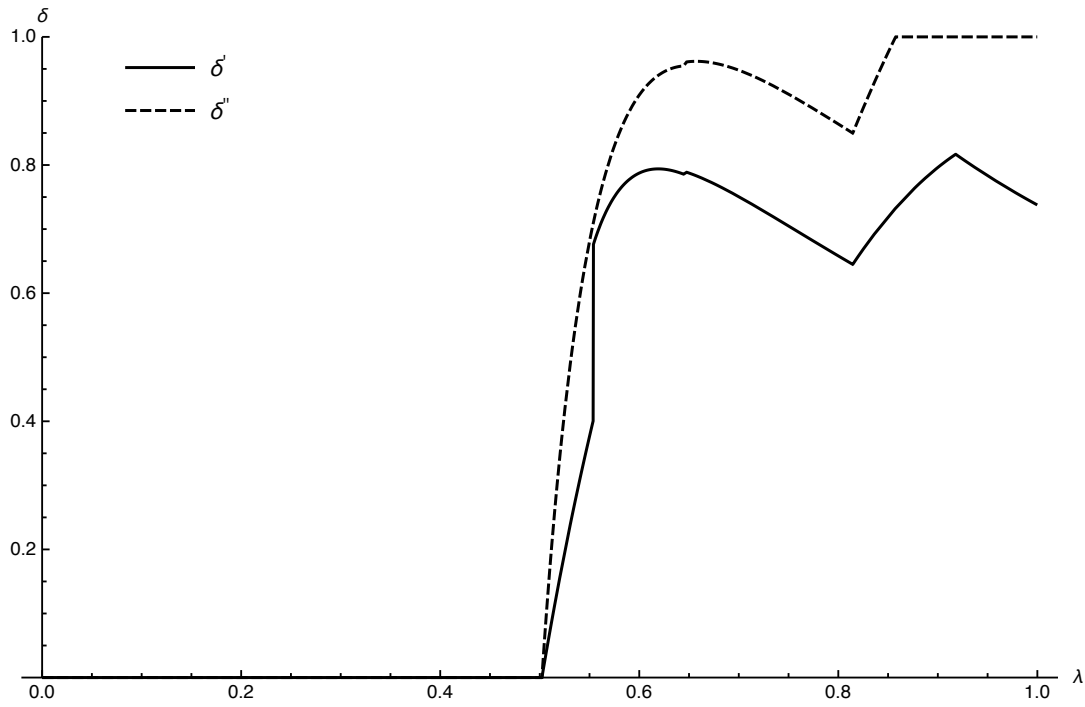


Figure 3.32: Discount Factor - Consumer's perspective

Note: The solid line represents the discount factor below which predation with no replacement is consumer welfare enhancing. The dashed line represents the discount factor below which predation with replacement is consumer welfare enhancing.

Proposition 3.7. *There exists a fixed cost K for which consumers prefer the predation outcome to the accommodation outcome when they are sufficiently impatient. They prefer predation even more when replacement occur.*

Proof. This result comes from the expected consumer surplus functions described in equations (3.15) and from the prices and investment levels described in Propositions 3.2, 3.3, 3.4 and 3.5. $\square$

From Figure 3.32, one can see that predation is preferred for a wider range of discount factors when there is replacement during the recoupment period. Furthermore, for a certain range of λ , predation is always preferred under replacement. Indeed,

the surplus loss experienced by consumers during the recoupment period does not overweight the gains from the exclusion period, when there is replacement.

Superposing Figure 3.32 and Figure 3.25 allows to determine for which discount factors both consumers and the online firm prefer predation. As represented in Appendix 3.G and stated in Corollary 3.1, the range of discount factors for which the market outcome is preferred by consumers is larger with replacement than without.²⁴

Corollary 3.1. *There exists a fixed cost K such that, for all values of λ , $\delta^* \leq \delta'$, $\delta^{**} \leq \delta''$ and $\delta' - \delta^* \leq \delta'' - \delta^{**}$.*

Proof. See Appendix 3.G. □

3.5.4 Does Society like Predation?

In this last subsection, I discuss the effect of predatory strategies on total surplus. I define the two different streams of expected total surplus over the two periods in equation (3.17).

$$\begin{aligned} TS^{accom} &= \pi_A^{accom} + \pi_B^{accom} - K + CS^{accom} + \delta(\pi_A^{accom} + \pi_B^{accom} + CS^{accom}) \\ TS^{pred1} &= \pi_A^{excl} + CS^{excl} + \delta(\pi_A^{recoup1} + CS^{recoup1}) \\ TS^{pred2} &= \pi_A^{excl} + CS^{excl} + \delta(\pi_A^{recoup2} + CS^{recoup2}) \end{aligned} \tag{3.17}$$

I compare these streams of total surplus to evaluate for which discount factors predation is maximising total welfare. Figure 3.33 represents the discount factors below which predation is total welfare enhancing (depending on the recoupment scenario).

Proposition 3.8. *There exists a fixed cost K such that society prefers the predatory outcome when it is very impatient and when the quality of the good is uncertain. Otherwise, society prefers accommodation.*

Proof. This result comes from the prices and investment levels described in Propositions 3.2, 3.3, 3.4 and 3.5, and from the profits and consumer surplus functions described in Proposition 3.6 and 3.7. □

²⁴However, the online firm and the consumers need not to have the same δ . On the contrary, in the real world, one could reasonably expect consumers to be rather short-sighted (or impatient) when it comes to evaluating their long-term surplus, and one could also expect “tech companies” like Amazon to be particularly forward looking when it comes to the profitability of their investment strategies. Under such expectations, predation is likely to be successful.

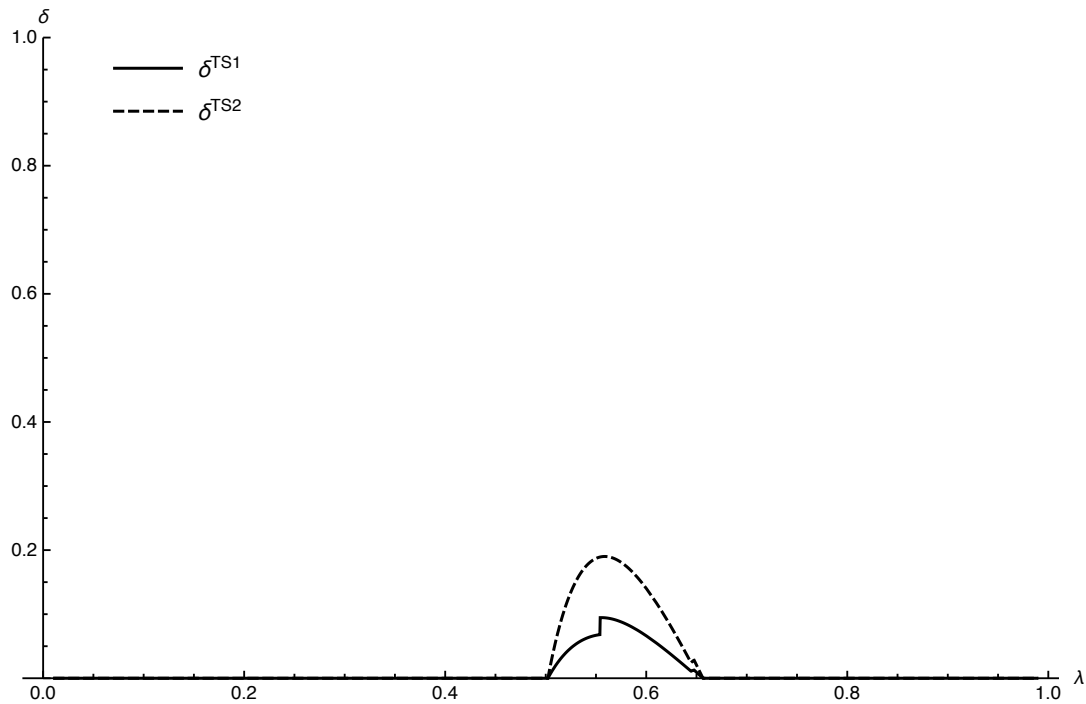


Figure 3.33: Discount Factor - Total Surplus

Note: The solid line represents the discount factor below which predation with no replacement is total surplus enhancing. The dashed line represents the discount factor below which predation with replacement is total surplus enhancing, assuming zero replacement costs.

Hence, predation is maximising social welfare only when the first (exclusion) period industry losses are not too big and when the second (recoupment) period consumer surplus losses are not too significant. Otherwise, predation harms total surplus.

Overall, if the policymaker is forward looking, it should try to prevent such monopolization strategies from online platforms. The question of which tools should be used to prevent an online firm to use its investment in delivery services for predatory purposes is not addressed here.

3.6 Extensions and Robustness Checks

In this last section, I consider a few extensions of the above model and explore some robustness checks.

3.6.1 Limit Pricing

In Appendix 3.H, I consider the case where the online firm maintains its pricing and investment strategy after predation, which corresponds to a limit pricing strategy. Figure 3.H.1 represents the profits that the firm would make during the recoupment period under limit pricing. Figure 3.H.2 represents the discount factor for which limit pricing is sustainable. It shows that limit pricing is almost never a profitable

strategy; if firm A is aiming at excluding its physical rival, it has to recoup its losses for the strategy to be profitable. Since limit pricing is often welfare enhancing, this model eliminates the possibility that predatory prices and investments remain the same post-exit.²⁵

3.6.2 Different fixed cost K

In Appendix 3.I, I compute the equilibrium prices and predatory investments for different values of the fixed cost K (0.02, 0.05, 0.1, 0.15 and 0.2 respectively). I show that the higher the fixed cost, the easier the predatory strategy is to implement. For very low values of the fixed cost, the online firm may have to price at cost, which is zero. The results are not qualitatively impacted by changes in K .

3.6.3 Predation versus Merger

In Appendix 3.J, I discuss the profitability of a merger strategy compared to the predation strategy discussed above. The merger strategy consists in buying the physical shop at a price equal to its profits (i.e. $\pi_B - K$) in the accommodation scenario during the first period, and enjoying monopoly profits with replacement during the second period. I assume that merger price is zero if $\pi_B - K \leq 0$. In other words, I compare a “predate-and-merge” strategy, in which the online firm chooses to predate in order to acquire the physical firm at zero cost, to a “standard” merger strategy, in which the online firm competes normally and acquires the firm at cost $\pi_B - K$. I show that predation is always more profitable than the standard merger.

3.6.4 Triangular Distribution

In Appendix 3.K, I consider the case when the population is geographically distributed according to a symmetric triangular distribution, where the physical store is located at the peak. Considering that physical stores are often located in the city centres of big cities, this extension allows to discuss the profitability of the predation strategy when the physical stores are located in the most densely populated areas of a country.

I no longer have closed-form best response functions, but I still have unique equilibria. The results are in the end very similar to what was obtained before. The physical store makes more profits and can afford to charge a higher price, as most of the local demand is now geographically close to it. The predation strategy does not

²⁵In other words, one should not expect companies like Amazon to maintain their current strategy forever.

differ much from the uniformly distributed case, but predation with replacement is now much more profitable than predation without replacement.

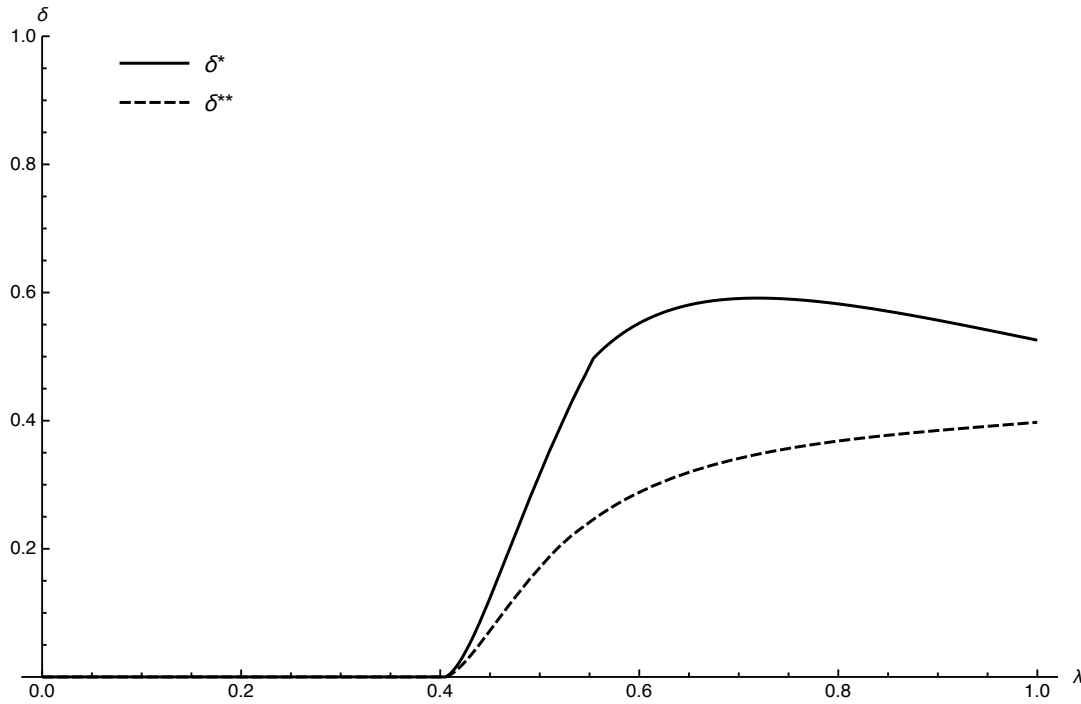


Figure 3.34: Discount Factor - Triangular Distribution

Note: The solid line represents the discount factor above which predation with no replacement is profitable. The dashed line represents the discount factor above which predation with replacement is profitable, assuming zero replacement costs. The consumers are assumed to be distributed according to a triangular distribution along the location segment.

In Figure 3.34, the discount factor under which predation is profitable is represented. One can notice that the gap between the two discount factors is larger, and in particular, the predation strategy without replacement is less profitable than before. This is due to the fact that predation is very costly when most of the population is located close to the shop. On the contrary, predation with replacement is even easier to sustain compared to the uniformly distributed case. This is due to the fact that recoupment with replacement is very profitable under that distribution. Hence, an online firm will find it very profitable to exclude and replace a physical competitor located in a densely populated area, especially for high quality products.

3.7 Conclusion

In this paper, I developed a model in which an online retailer and a physical retailer compete in price. Consumers' utilities are such that some of them may choose to buy the homogeneous good directly online, and some other others may choose to visit the physical shop (or not buy). After their visit, they may choose between buying from the store or ordering online (or not buy).

The online firm has the possibility to invest in delivery services, such that the waiting time experienced by online customers is less costly to them. I compute the equilibrium prices in the presence of such investments and compare them to the case where no investments are possible, and I show that, without predatory intent, the online firm decides to not invest much, such that the prices and profits of both firms are almost unaffected by the presence of such investments. When considering a two-period model in which the physical firm has to pay a fixed cost to remain active during the second period, I show that a patient online firm will find it profitable to invest aggressively and price low in order to exclude its physical competitor from the market and enjoy monopoly profits during the second period. I consider two types of predation strategy: one in which the online firm replaces the physical competitor post-exclusion by building (or buying) a local store, and one in which it remains strictly online during the recoupment period. I show that an online firm will find it more profitable to predate if it replaces its competitor in the second period. From a consumer point of view, predation is preferred if they are impatient enough, especially when there is replacement during the second period. From a societal welfare point of view in contrast, predation is often harmful.

These results match many features of the current Retail Apocalypse. The wave of physical retailer bankruptcies, the low profitability of Amazon and its high level of investments in delivery services do not match my one-period model predictions but do match my two-period predatory scenario. In addition, my model describes the incentive to build physical stores in densely populated areas to sell high quality products, like Amazon 4-star. Ultimately, the fact that Amazon Prime membership fee increased a second time in 2019 suggests that Amazon has now enough market power to increase its prices.

There are other elements not discussed in this paper that could contribute to the success of such a predation strategy. Amazon is a multi-product seller with a multi-market presence, allowing it to recoup losses occurring in one market using benefits earned on another one. Also, due to its two-sided nature, the market in which Amazon is active has network features creating strong barriers to entry for potential competitors.²⁶ From a corporate finance perspective, small shops are subject to credit constraints that firms of the size of Amazon do not experience and which can explain the lack of physical retailer creation (or re-entry).²⁷ In addition, Amazon prime memberships is a bundle deal in which the free delivery services are sold jointly with Amazon prime video access, which can contribute to such a predation

²⁶See, for example, Farrell and Katz (2005) and Vasconcelos (2015)

²⁷See the “Long Purse” theories of predation (e.g. Fudenberg and Tirole (1986), Bolton and Scharfstein (1990)).

strategy through horizontal foreclosure effects.²⁸ Ultimately and unexpectedly, the current Covid-19 pandemic hit the retail industry in an unforeseen manner. While all physical retail outlets had to shut down all activity during months (often paying rents forcing them to permanently shut down), Amazon and online deliveries in general have never been as successful.

This paper aims to contribute to a general questioning about the current monopolization strategies of big “tech companies”. In that sense, it leads to several research avenues. On the one hand, from a policy perspective, work needs to be done on how should this sector be regulated. On the other hand, from a theoretical perspective, more models studying the competition of online and physical retailer deserve to be studied, in particular multi-homing practices, in which an internet platform is distributing products from competitor while selling its own products.

²⁸See Whinston (1990) for instance.

Appendix

3.A Proof of Proposition 3.1

Depending on the values of p_A and p_B , the demand (and the profits) take different forms. In the benchmark case, six different configurations can occur:

- Case 1: $0 < \beta_o < \beta_{ls} < 1$ and $0 < t_{os} \leq t_{ol} \leq t_l < \frac{1}{2}$
- Case 2: $0 < \beta_{ls} \leq \beta_o < 1$ and $0 < t_l \leq t_s \leq t_{os} < \frac{1}{2}$
- Case 3: $0 < \beta_o < 1 \leq \beta_{ls}$ and $0 < t_{ol} \leq t_l < \frac{1}{2}$
- Case 4: $0 < \beta_{ls} < 1 \leq \beta_o$ and $0 < t_l \leq t_s < \frac{1}{2}$
- Case 5: $0 < \beta_{ls} < 1$ and $0 < t_{os} \leq t_{ol} \leq \frac{1}{2} \leq t_l$
- Case 6: $\beta_{ls} \geq 1$ and $0 < t_{ol} \leq \frac{1}{2} \leq t_l$

There are also two extra physical monopoly cases in which both β_o and β_{ls} are above one: one in which $t_l < \frac{1}{2}$ and one in which $t_l \geq \frac{1}{2}$. I solve this game in two steps. First, I compute the best response functions for each of these configurations, evaluate their intersection and check whether these equilibrium prices are consistent with the parameter range described above. Second, for those equilibria that are consistent with their parameter range, I check whether there are profitable deviations outside this parameter range. For all values of λ , there is a unique solution to the game. For $0 < \lambda < \tilde{\lambda} \approx 0.84$, the profits take the “Case 1” form and the equilibrium prices solve the following system of best response functions:

$$\begin{aligned}
 p_A(p_B, \lambda) &= \frac{1 + 2p_B\lambda - 4p_B\lambda^2 + 2p_B\lambda^3 - \sqrt{3(-1 + \lambda)^2\lambda(1 + 2\lambda)(-1 + (-1 + p_B)^2\lambda) + (1 + 2p_B(-1 + \lambda)^2\lambda)^2}}{3(-1 + \lambda)^2(1 + 2\lambda)} \\
 p_B(p_A, \lambda) &= \frac{2\lambda(p_A + \lambda) - \sqrt{\lambda^2(2p_A\lambda + \lambda^2 + p_A^2(7 + 3\lambda(\lambda - 2)))}}{3\lambda^2}
 \end{aligned} \tag{3.18}$$

For $\tilde{\lambda} \leq \lambda < 1$, the profits take the “Case 5” form. The profits of the physical firm are maximised by the price level making t_l exactly equal to $1/2$, which is

$p_B^l(\lambda) = \frac{2\lambda-1}{2\lambda}$. Plugging this expression into firm A's best response function, one obtains the following equilibrium prices.

$$\begin{aligned} p_A(\lambda) &= \frac{8\lambda - 10\lambda^2 + 4\lambda^3 - \sqrt{-3(1-\lambda)^2(1+2\lambda)(4\lambda-1) + 4(4\lambda-5\lambda^2+2\lambda^3)^2}}{6(1-\lambda)^2(1+2\lambda)} \\ p_B(\lambda) &= \frac{2\lambda-1}{2\lambda} \end{aligned} \quad (3.19)$$

3.B Proof of Proposition 3.2

Depending on the values of p_A , p_B and s , the demand (and the profits) take different forms. In addition to the six cases described in 3.A, two more cases can arise:

- Case 7: $\beta_o \leq 0 < \beta_{ls} < 1$ and $0 < t_{os} \leq t_{ol} < \frac{1}{2}$
- Case 8: $\beta_o \leq 0 < 1 \leq \beta_{ls}$ and $0 \leq t_{ol} < \frac{1}{2}$

There are also three extra online monopoly cases in which β_{ls} is below zero: one in which $\beta_o \geq 1$, one in which $\beta_o \leq 0$ and one in which $0 < \beta_o < 1$. Similarly as before, I solve this game in two steps. First, I compute the best response functions for each of these configurations, evaluate their intersection and check whether these equilibrium prices are consistent with the parameter range described above. Second, for those equilibria that are consistent with their parameter range, I check whether there are profitable deviations outside this parameter range. For all values of λ , there is a unique solution to the game. For $0 < \lambda < \lambda^* \approx 0.81$, the profits take the “Case 1” form and the equilibrium prices and investment solve the following system of best response functions:

$$\begin{aligned} p_A(p_B, \lambda) &= \frac{1 + 2p_B\lambda - 4p_B\lambda^2 + 2p_B\lambda^3 - \sqrt{3(-1+\lambda)^2\lambda(1+2\lambda)(-1+(-1+p_B)^2\lambda) + (1+2p_B(-1+\lambda)^2\lambda)^2}}{3(-1+\lambda)^2(1+2\lambda)} \\ p_B(p_A, s, \lambda) &= \frac{2\lambda(p_A + \lambda - s\lambda) - \sqrt{\lambda^2(2p_A(1-4s)\lambda + \lambda^2(1-2s+4s^2) + p_A^2(7+3\lambda(\lambda-2)))}}{3\lambda^2} \\ s(p_A, p_B, \lambda) &= \frac{1}{3} \left(2 - \frac{\lambda\sqrt[3]{2}}{\Theta} - \frac{\Theta}{\lambda\sqrt[3]{2}} \right) \end{aligned} \quad (3.20)$$

where

$$\begin{aligned} \Theta &= \left(-27(-1+p_A)p_A^2\lambda^2 + (2+27p_A(-1+2p_AP_B))\lambda^3 \right. \\ &\quad + 27p_A(3p_A^2 + (-1+p_B)^2 - 4p_AP_B)\lambda^4 + 54p_A^2(-p_A+p_B)\lambda^5 \\ &\quad \left. + \sqrt{-4\lambda^6 + \lambda^4(2\lambda + 27p_A(-p_A^2(-1+\lambda)^2(1+2\lambda) + \lambda(-1+(-1+p_B)^2\lambda) + p_A(1+2p_B(-1+\lambda)^2\lambda)))^2} \right)^{\frac{1}{3}} \end{aligned} \quad (3.21)$$

For $\lambda^* \leq \lambda < \lambda^{**} \approx 0.92$, the profits take the “Case 5” form. The profits of the physical firm are maximised by the price level making t_l exactly equal to $1/2$, which is $p_B^l(\lambda) = \frac{2\lambda-1}{2\lambda}$. The equilibrium prices and investment then solve the following system of equations.

$$\begin{aligned} p_A(p_B, \lambda) &= \frac{2 + 4p_B(1-\lambda)^2\lambda - \sqrt{1 + \lambda(3(3-2\lambda)\lambda + 16p_B^2(1-\lambda)^4\lambda - 4p_B(1-\lambda)^2(-1+6\lambda))}}{6(1-\lambda)^2(1+2\lambda)} \\ p_B(\lambda) &= \frac{2\lambda-1}{2\lambda} \\ s(p_A, p_B, \lambda) &= \frac{(-2\lambda + \Phi)^2}{-6\lambda\Phi} \end{aligned} \quad (3.22)$$

where

$$\begin{aligned} \Phi &= \left(8\lambda^3 - 108p_A^3(1-\lambda)^2\lambda^2(1+2\lambda) - 27p_A\lambda^2(1+4p_B\lambda) + 108p_A^2\lambda^2(1+2p_B(1-\lambda)^2\lambda) + \right. \\ &\quad \left. + \sqrt{\lambda^4(-64\lambda^2 + (8\lambda + 27p_A(-1-4p_B\lambda - 4p_A(-1-2p_B(1-\lambda)^2\lambda + p_A(1-\lambda)^2(1+2\lambda))))^2} \right)^{\frac{1}{3}} \end{aligned} \quad (3.23)$$

For $\lambda^{**} \leq \lambda < 1$, the profits take the “Case 5” form. The profits of the physical firm are maximised by a price level which is below p_B^l . The equilibrium prices and investment then solve the same system of equation as before, except that the second equation is now replaced by Firm B’s best response function.

$$p_B(p_A, s, \lambda) = \frac{-1 + 4p_A - 4p_A^2(1-\lambda)^2 + 4(1-s)\lambda}{8\lambda} \quad (3.24)$$

3.C Proof of Proposition 3.3

Depending on the values of p_A , p_B and s , the demand (and the profits) take different forms. The different possible cases are described in 3.A and 3.B. In the following, the fixed cost K is assumed to be equal to 0.08. It corresponds to the gross profits of the physical firms when $\lambda = \lambda_1 \approx 0.5$. Hence, up to that value of λ , the equilibrium prices and investments are the same than in the static game.

For the online firm, I solve the following Langrangian problem:

$$L(p_A, s, \omega) = \pi_A(p_A, p_B, s) - \omega \times \pi_B(p_A, p_B, s) \quad (3.25)$$

Similarly as before, I solve this game in two steps. First, for each of the possible configurations, I compute the first order conditions of the above Langrangian and firm B’s profit maximisation, solve this system of four equations and check whether these equilibrium prices and investments are consistent with the parameter range

described above. Second, for those equilibria that are consistent with their parameter range, I check whether there are profitable deviations outside this parameter range. For all values of λ , there is a unique solution to the game

For $\lambda_1 \leq \lambda < \lambda_2 \approx 0.645$, the profits take the “Case 1” form and the equilibrium prices and investment solve the following system of first order conditions:

$$\begin{aligned}
 \frac{\partial L}{\partial p_A} = 0 &\Leftrightarrow \frac{2p_A - \lambda - 3p_A^2(-1 + \lambda)^2(1 + 2\lambda) - 2p_A p_B(-1 + \lambda)^2\lambda(-2 + \omega) + (-1 + p_B)\lambda^2(-1 + p_B - 2p_B\omega)}{(-1 + s)\lambda} = 0 \\
 \frac{\partial L}{\partial s} = 0 &\Leftrightarrow \frac{-(-1 + s)^2 s \lambda + p_A^3(-1 + \lambda)^2(1 + 2\lambda) + p_A^2(-1 + p_B(-1 + \lambda)^2\lambda(-2 + \omega))}{(-1 + s)^2 \lambda} \\
 &\quad + \frac{-p_B(-1 + p_B^2)\lambda^3\omega + p_A\lambda(1 + (-1 + p_B)\lambda(1 - p_B + 2p_B\omega))}{(-1 + s)^2 \lambda} = 0 \\
 \frac{\partial L}{\partial \omega} = 0 &\Leftrightarrow \pi_B = 0.08 \\
 \frac{\partial \pi_B}{\partial p_B} = 0 &\Leftrightarrow \frac{p_A^2 - 2p_A(1 + p_A - 2p_B)\lambda + (-1 + p_A^2 + p_B(4 - 3p_B - 4s) + 2s)\lambda^2}{-1 + s} = 0
 \end{aligned} \tag{3.26}$$

For $\lambda_3 \approx 0.648 \leq \lambda < 1$, the profits take the “Case 7” form and the equilibrium prices and investment solve the following system of first order conditions:

$$\begin{aligned}
 \frac{\partial L}{\partial p_A} = 0 &\Leftrightarrow \frac{-1 + s + (-1 + p_B)^2\lambda + s(-2 + 2p_B + s)\lambda + 3p_A^2(3 - 2\lambda)\lambda}{-1 + s} \\
 &\quad + \frac{p_A(4 - 4s - 2p_B(-2 + \lambda)\lambda(-2 + \omega)) - 2p_B(-1 + p_B + s)\lambda\omega}{-1 + s} = 0 \\
 \frac{\partial L}{\partial s} = 0 &\Leftrightarrow \frac{-s^3 + p_A\lambda(1 + (p - A - p_B)(p_B + p_A(-3 + 2\lambda))) + p_B\lambda(\lambda + (p_A - p_B)(p_A(-2 + \lambda) + p_B\lambda))\omega}{(-1 + s)^2} \\
 &\quad + \frac{s^2(2 + \lambda(p_A p_B \lambda \omega)) - s(1 + 2\lambda(p_A + p_B \lambda \omega))}{(-1 + s)^2} = 0 \\
 \frac{\partial L}{\partial \omega} = 0 &\Leftrightarrow \pi_B = 0.08 \\
 \frac{\partial \pi_B}{\partial p_B} = 0 &\Leftrightarrow \frac{\lambda(2p_A(-1 + 2p_B + s) + p_A^2(-2 + \lambda) - (-1 + p_B + s)(-1 + 3p_B + s)\lambda)}{-1 + s} = 0
 \end{aligned} \tag{3.27}$$

For $\lambda_1 \leq \lambda < \lambda_2$, the profits take the “Case 5” form. The profits of the physical firm are maximised by the investment level making β_o exactly equal to 0, which is $s_o^0(p_A, \lambda) = \frac{p_A}{\lambda}$. For this interval of λ , the equilibrium prices solve the above system of equations in which the second first order condition is replaced by $s = s_o^0(p_A, \lambda)$.

3.D Proof of Proposition 3.4

Depending on the values of p_A , p_B and s , the demand (and the profits) take different forms. In the recoupment without replacement scenario, it can take only two shapes: either all consumers are served (i.e. $\beta_o \leq 0$), or only some of them are (i.e. $\beta_o > 0$).

For $\lambda < \lambda^* \approx 0.55$, only some consumers are served, and maximising π_A with respect to p_A and s yields the following solutions:

$$\begin{aligned} p_A &= \frac{\lambda}{2} \\ s &= \frac{-4\lambda^2 + 4\lambda\Psi - \Psi^2}{6\lambda\Psi} \end{aligned} \quad (3.28)$$

where

$$\Psi = \left(8\lambda^3 - 27\lambda^4 + 3\sqrt{3}\sqrt{\lambda^7(-16 + 27\lambda)} \right)^{1/3} \quad (3.29)$$

For $\lambda \geq \lambda^*$, it is more profitable to serve all consumers. The profit maximising levels of p_A and s are then:

$$\begin{aligned} p_A &= \lambda^2 \\ s &= \lambda \end{aligned} \quad (3.30)$$

3.E Proof of Proposition 3.5

Depending on the values of p_A and s , the demand (and the profits) take different forms. In the recoupment with replacement scenario, four different configurations can occur:

- Case 1: $0 < \beta_o < 1$ and $0 < t_{ol} \leq t_l < \frac{1}{2}$
- Case 2: $0 < \beta_o < 1$ and $0 < t_{ol} < \frac{1}{2} \leq t_l$
- Case 3: $\beta_o \leq 0$ and $0 < t_{ol} \leq \frac{1}{2}$
- Case 4: $\beta_o \geq 1$ and $0 < t_l < \frac{1}{2}$

Similarly as before, I solve this game in two steps. First, I compute the best response functions for each of these configurations, evaluate their intersection and check whether these equilibrium prices are consistent with the parameter range described above. Second, for those equilibria that are consistent with their parameter range, I check whether there are profitable deviations outside this parameter range. For all values of λ , there is a unique solution to the game. The profits take the “Case 1” form and equilibrium price and investment solve the following system of best response functions:

$$p_A(s, \lambda) = \frac{-1 + 2\lambda^2(2 + (-1 + s)\lambda) + \sqrt{1 + \lambda(3 + \lambda(4 + \lambda(-8 + 25\lambda + 2(s - 9s\lambda + 8(-1 + s)\lambda^2 + 2(-1 + s)^2\lambda^3))))}}{-3 + 9\lambda}$$

$$s(p_A, \lambda) = \frac{1}{3} \left(2 - \frac{\lambda\sqrt[3]{2}}{\Theta} - \frac{\Theta}{\lambda\sqrt[3]{2}} \right) \quad (3.31)$$

where

$$\Theta = \left(2\lambda^3 + 27p_A^3\lambda^2(-1 + 3\lambda) + 27p_A^2\lambda^2(1 - 4\lambda^2) + 27p_A\lambda^3(-1 + \lambda + \lambda^2) + \sqrt{-4\lambda^6 + \lambda^4(2\lambda + 27p_A(p_A - \lambda)(1 - \lambda(1 + \lambda) + p_A(-1 + 3\lambda)))^2} \right)^{\frac{1}{3}} \quad (3.32)$$

3.F Supporting graphs of Remark 3.1

In this Appendix section, I compare the price and profit levels of the one-period model with investment to the ones in the benchmark case. The presence of investments has little influence on price and profits levels.

Figure 3.F.1: Comparison of Prices in the Static Game

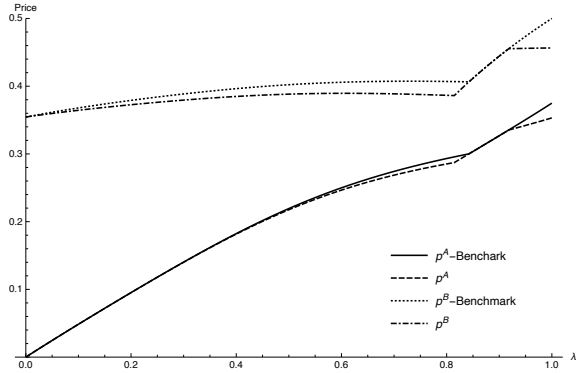
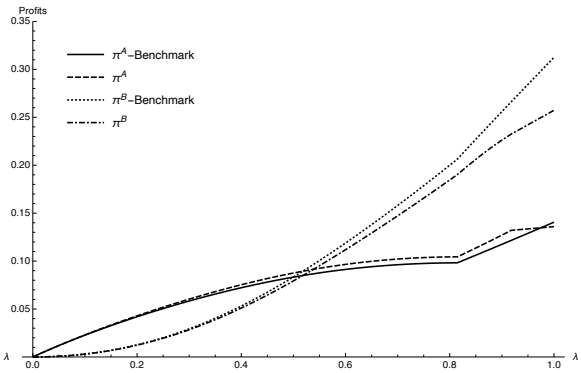


Figure 3.F.2: Comparison of Profits in the Static Game



3.G Discount Factors comparison

In this Appendix section, I compare the discount factor thresholds of the online firm to the ones of the consumers. The range of parameter values for which both consumers and the online firm prefer predation is larger when there is replacement.

Figure 3.G.1: Comparison of Discount Factors - Predation without Replacement

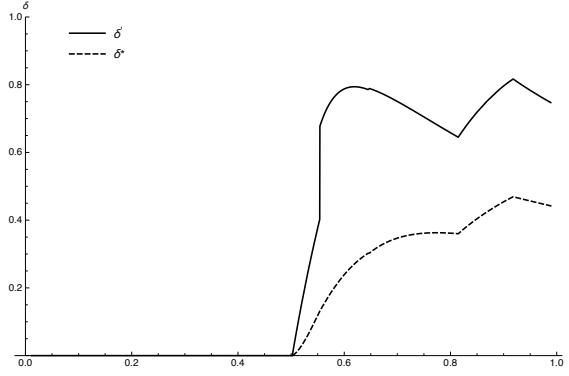
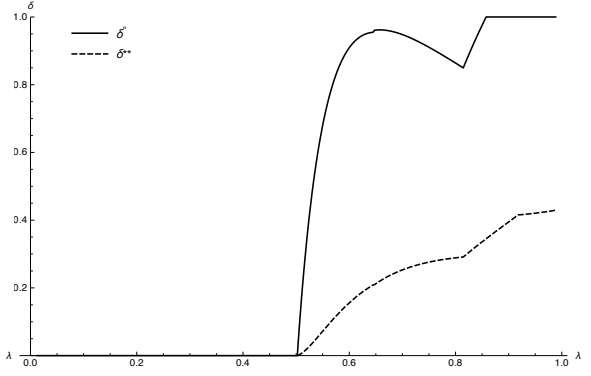


Figure 3.G.2: Comparison of Discount Factors - Predation with Replacement



3.H Extension: Limit Pricing

In this Appendix section, I discuss the profitability of a limit pricing strategy consisting in maintaining predatory price and investment post-exclusion. The first figure represents the second period profits of the online firm if it maintains its predatory price and investment of level (of the first period). The second figure represents the discount factor above which limit pricing is profitable.

Figure 3.H.1: Recoupment/Limit Pricing

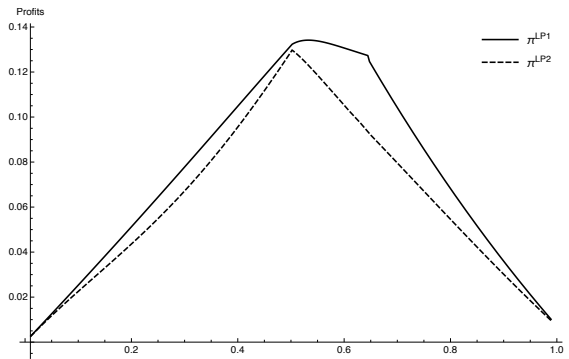
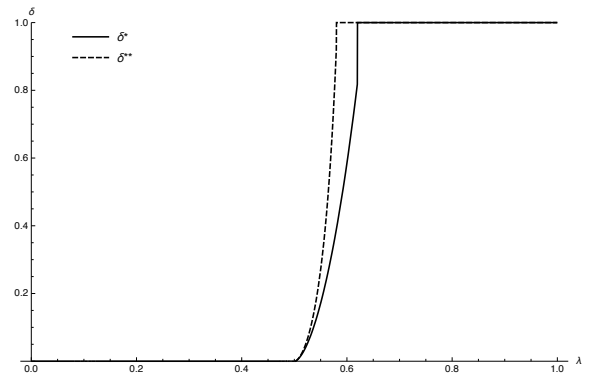


Figure 3.H.2: Discount Factor - Limit Pricing



Note: In Figure 3.H.1, the solid line represents the period 2 profits under limit pricing without replacement. The dashed line represents the period 2 profits under limit pricing with recoupment. In Figure 3.H.2, the solid line represents the discount factor above which limit pricing with no replacement is profitable. The dashed line represents the discount factor above which limit pricing with replacement is profitable, assuming zero replacement costs.

3.I Robustness Check: Different Fixed Costs

In this Appendix section, I show that the exclusion strategy consisting in increasing investment level and decreasing price is robust to changes in the physical firm's fixed costs. The following figures represent the exclusion price and investment level for K equal to 0.02, 0.05, 0.1, 0.15, 0.2, respectively.

Figure 3.I.1: Prices and Investment - Exclusion period - $K = 0.02$

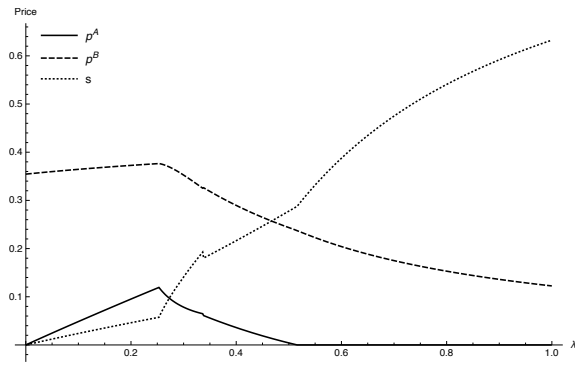


Figure 3.I.2: Prices and Investment - Exclusion period - $K = 0.05$

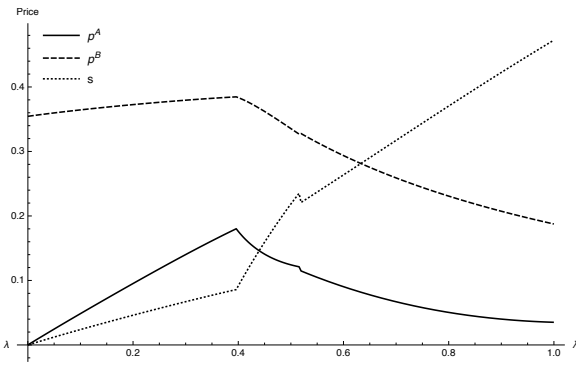


Figure 3.I.3: Prices and Investment - Exclusion period - $K = 0.1$

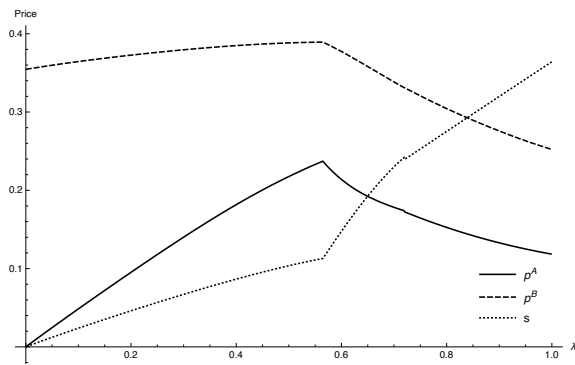


Figure 3.I.4: Prices and Investment - Exclusion period - $K = 0.15$

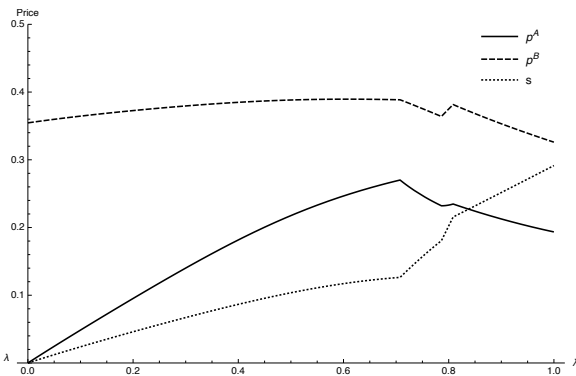
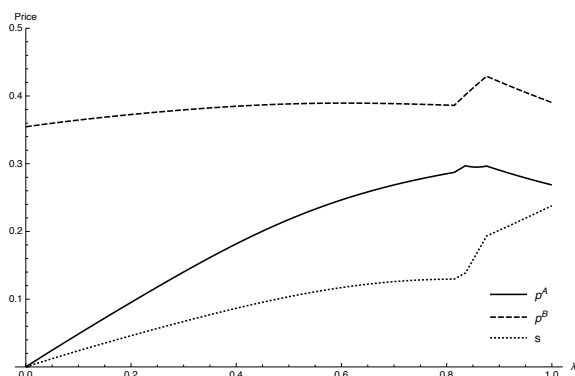


Figure 3.I.5: Prices and Investment - Exclusion period - $K = 0.2$



3.J Extension: Merger vs Predation

In this Appendix section, I compare the payoffs of the online firm during the exclusion stage to its profits net of a merger cost equal to the payoffs of the physical firm. I assume that the cost of merger is zero when the profits of the physical shop are equal or below zero. The following figure shows that a predation strategy is always more profitable than a merger strategy.

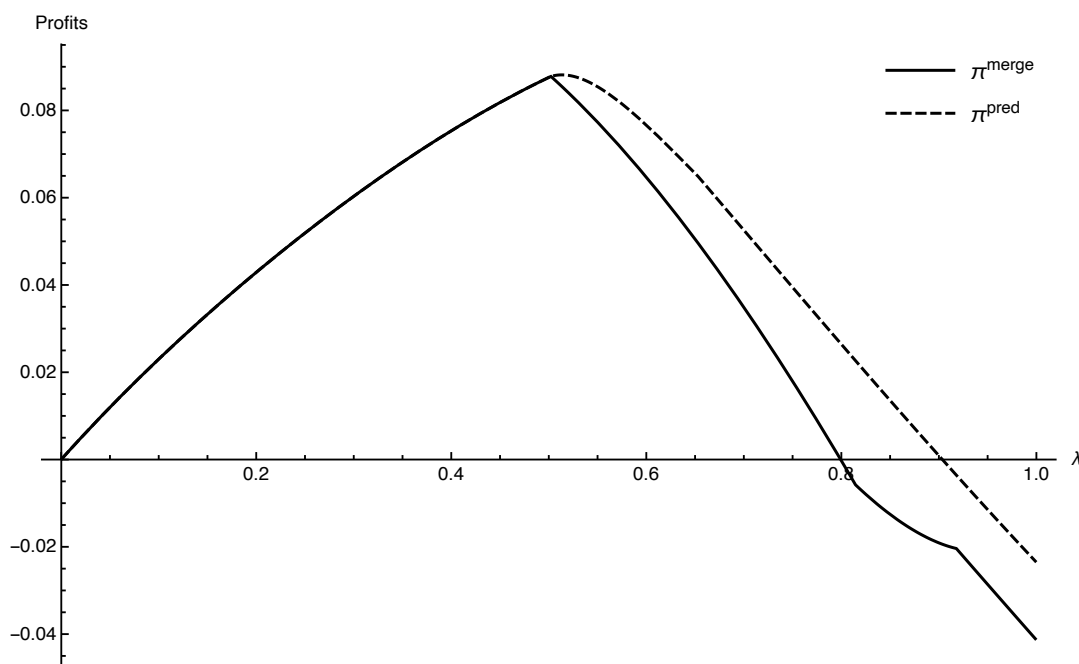


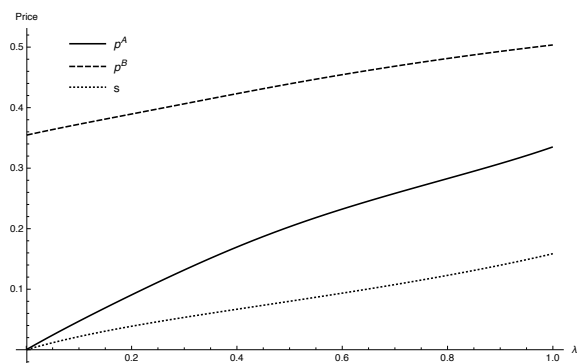
Figure 3.J.1: Equilibrium profits - Predation vs. Merger

Note: The dashed line represents the period one exclusion profits under the predation strategies. The solid line represents the period one accommodation profits minus the merger cost (i.e. $\pi_B - K$).

3.K Extension: Triangular distribution

In this last Appendix subsection, I investigate the online firm's incentives to undertake predatory strategies if the consumers are distributed according to a triangular distribution along the location segment. The physical shop is located at the peak of the distribution; hence, it is located at the most densely populated area. The main difference with the uniform case is that the physical shop is particularly profitable, and excluding it from the market requires bigger profit sacrifices from the online firm. Replacing the physical shop post-exclusion is particularly profitable in this set-up.

Figure 3.K.1: Prices and Investment - Accommodation



Note: The consumers are assumed to be distributed according to a triangular distribution along the location segment.

Figure 3.K.2: Profits - Accommodation

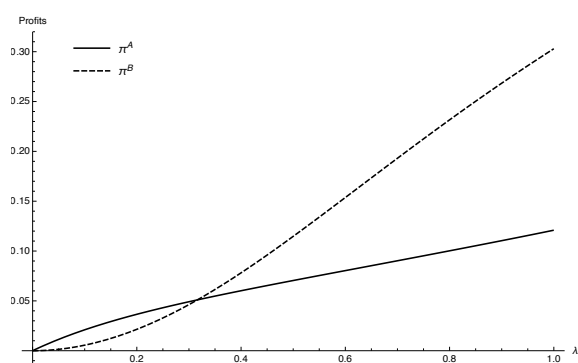
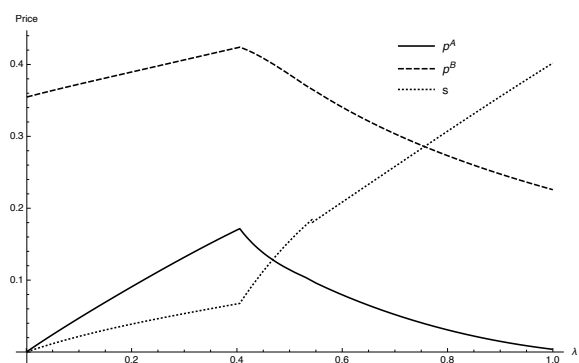


Figure 3.K.3: Prices and Investment - Exclusion



Note: The consumers are assumed to be distributed according to a triangular distribution along the location segment.

Figure 3.K.4: Profits - Exclusion

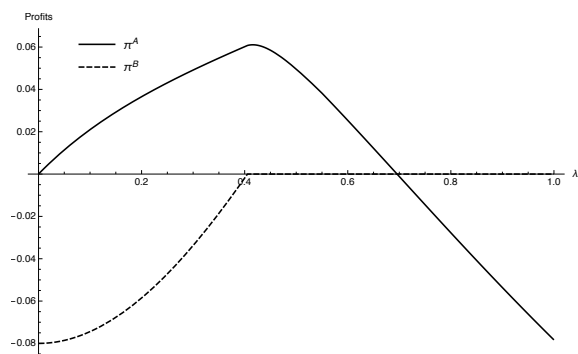
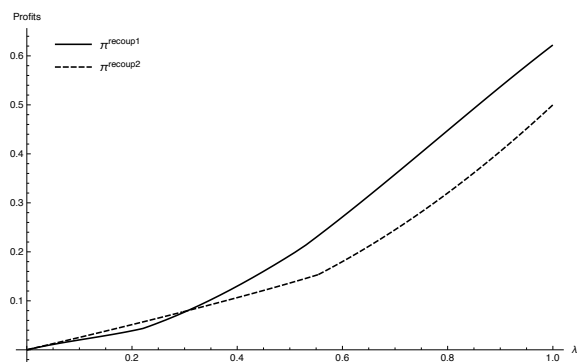


Figure 3.K.5: Profits comparison - Recoupment - Replacement/No Replacement



Note: The consumers are assumed to be distributed according to a triangular distribution along the location segment.

General Conclusion

By their nature, digital markets challenge the classical conceptions of competition economics and industrial organisation. A firm's key to success in such markets is its capacity to anticipate which investment it should make, to exploit adequately the immense amount of data it collects, and to remain competitive and appealing to consumers. Firms no longer focus on their short-run profits but on their long-term growth, and their revenues are now based on more sophisticated systems than published linear prices (e.g. targeted ads). In addition, the “winner-takes-all” nature of these markets (due to network effects and two-sided structure) triggered the rise of sometimes-called “tech giants”, whose vertical structure is more and more complicated. As a result, in recent years, the most important competition cases both in Europe and in the USA are often about technology-intensive sectors, and the current investigation of the competition authority about Amazon Marketplace highlights the current challenges of competition policy.²⁹

In this context, there is a need for updated theoretical frameworks to understand the dynamics of such markets and the incentives of firms competing within them. This dissertation contributes to this debate and provides insights on the influence of vertical integration on technology adoption patterns (Chapter 1), the vertical integration incentives in the presence of a cost-reducing technology (Chapter 2), and the use of delivery services for predatory intent by an online retailer (Chapter 3).

In Chapter 1, I studied the influence of a market's vertical structure on the timing of technology adoption. Using a duopoly model in which vertical chains compete in quantity and bargain over their bilateral contracts, I explore the differences in timing of adoption of a cost-reducing technology depending on whether the firms are integrated or not. In particular, the study of the asymmetric case, in which only one firm is integrated, allows to disentangle the mechanisms affecting the speed of adoption. I show that adoption is influenced not only by adopter's vertical structure

²⁹European Commission Case 40462: *Amazon Marketplace*. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/IP_19_4291.

but also by its competitor's one. I show that this pattern is observed regardless of the type of adoption game explored. Finally, I study the optimal timing of adoption, and develop a taxation policy to maximise total surplus.

In Chapter 2, I further explore the relationship between vertical integration and technology adoption. Using the same duopoly model as in Chapter 1, I endogenise the integration decision: starting from a situation in which both firms are separated, I study how the presence of a cost-reducing technology affects the structure of the market. I show that even in a purely symmetric set-up with no synergies or foreclosure incentives, an asymmetric integration equilibrium in which only one firm chooses to vertically integrate can arise. This is due to the fact that the incentives to become integrated stem from the effect of this integration on the speed of adoption, which depends on the vertical structure of the competitor. I show that this asymmetric integration equilibrium can be observed under both types of adoption games. Ultimately, I show that even though integration generally harms consumers, total surplus is often maximised by the market's outcome.

These first two chapters contribute to the current debate about vertical mergers. As Slade (2019) describes it, the technology, media and telecommunication sector is one of the most active industries in terms of vertical integrations. It is also an innovative industry, in which the adoption of new technologies (e.g. optic fibre, 5G) is a key driver of profitability. The assessment of such vertical mergers should take into account their linkage with technology adoption incentives. The very recent vertical merger guidelines issued by the U.S. Department of Justice and the Federal Trade Commission³⁰ fail to capture this linkage but head towards an understanding of vertical relations that go beyond static price considerations.

In Chapter 3, I explore the competition of an online and a physical retailer in a market characterised by transportation costs and waiting costs. I model a demand in which consumers are differentiated in terms of patience and location, and I evaluate the profit maximising strategies of the two types of retailer in that context. In particular, I allow the online firm to invest so as to reduce delivery time (i.e. reduce the importance of patience in the consumer's utility function), and I compare the output of a static set-up to a two-period model. I show that in a static set-up, an online retailer does not find it profitable to invest much into delivery services, whereas in a two-period model, investment becomes attractive as it allows to exclude the physical competitor and enjoy monopoly profits in the second period. I show that such strategy is particularly attractive if the online firm plans on replacing the physical retailer with its own physical shop. Finally, I show that impatient

³⁰ *Vertical Merger Guidelines*, U.S. Department of Justice and the Federal Trade Commission (June 30, 2020). Retrieved from <https://www.justice.gov/atr/page/file/1290686/download>

consumers may enjoy such predatory investment strategy, but overall, total surplus decreases as a result of it.

This third chapter offers insights on the current Retail Apocalypse and on Amazon's recent strategies, which are under scrutiny at the European Commission. The non-profitability of Amazon (which stopped exactly at the start of the Retail Apocalypse) has been a long-lasting puzzle, which could be partially explained by the immense of cost that one-day and same-day deliveries caused to this company. The opening of Amazon four-star and other physical utilities in the middle of the biggest crisis the physical retailing experienced in years can also be perplexing. My chapter tries to offer a consistent economic story underlying these patterns, and these issues are sure to provide important challenges for future research.

Overall, this dissertation suggests that competition authorities' treatment of vertical integrations and abuse of dominance should go beyond simple price strategies and static competition models. They should broaden their perspective to long-run non-price strategies. In a context where digital markets are increasingly important and characterised by complex vertical structures and long-term investment strategies, it seems essential to adjust our standard frameworks of analysis accordingly.

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