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This thesis is dedicated to my boys
Ale & Enzo

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the Toulouse School of Economics is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

Statement of conjoint work

I confirm that Chapter 3 was jointly co-authored with Shagun Khare of Toulouse School of Economics and Alan Acosta of Universidad de San Andrés.

Abstract

This thesis in applied microeconomics is composed of three chapters, each one addressing a different question.

The first chapter, *"Sequential distribution in the presence of Piracy"*, shows how firms can exploit the timing of the release of digital content as a way to mitigate the effects of piracy, in a world where some piracy is unavoidable. We develop an analytical model where a monopolist produces a particular good, and it can choose the time at which its product is available to consumers. On top of deciding on prices, the monopolist also chooses the share of the product it releases at each period. In the absence of piracy, firm's profits are independent of the way in which content is released. However, when piracy is a real threat, the firm can soften its effect by strategically selecting the share of the product offered in each period, changing consumers' valuation and making piracy less attractive from their perspective. The monopolist benefits from releasing content in two different periods in an asymmetric way which find analogies in real life examples such as the market of specialised software tools or of TV shows.

The second chapter, *"Shill bidding in common value auctions"*, presents the effects of a particular cheating environment in common value auctions. Shill bidding consists of placing anonymous bids on the seller's behalf to artificially drive up the prices of the auctioned item. We build a simple model to understand the incentives a seller has to shill bid in an English common value auction where the bidders' private information is drawn from a discrete distribution. We show how the discreteness affects the seller's ex-ante expected gain of shill bidding, and we also show how the seller updates his shill bid based on the new information he receives as the auction goes on. We find that if the number of signals is low, the seller might be better off refraining from participating even when bidders are fully myopic. Moreover, for any number of signals in the auction, if the number of participants is sufficiently high, the shill bidding strategy always deteriorates the seller's expected profits.

The third chapter, *"Physician convenience and cesarean section delivery"*, is co-authored with Shagun Khare and Alan Acosta. This paper analyses the causes that might explain the high rate of cesarean section in Buenos Aires, Argentina, that far exceeds the World Health Organization recommendation. The supplier-induced demand hypothesis, which predicts more c-section deliveries than otherwise medically needed, might be the reason for this disparity. In this paper, using a survey of pregnant women in Buenos Aires, we study one aspect of the physician's incentives to induce demand: convenience. We look at whether a woman's chance of getting a c-section depends on the period of delivery, i.e. whether it is a working day or not. Setting aside scheduled c-sections, we find that convenience matters, but only in private hospitals. We also find that women who state that they prefer c-sections over natural births have a higher chance of having a c-section in private hospitals. While physicians' convenience and mothers' preferences do matter, our research finds that the institutional environment plays a defining role in how much these matters.

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Chapter 1

Sequential Distribution in the Presence of Piracy

1.1 Introduction

The rise of Internet access along with the growth of digital content has enabled digital piracy to flourish around the world. If there is no "positive effect" on the demand side (e.g., discovering the unknown, accessing the inaccessible, sampling or network effects), the effect of piracy on firms that produce the original products is unambiguous: piracy reduces its sales and also makes it harder to extract revenue from their remaining consumers (Johnson, 1985; Goldman, 2010; Smirke, 2014).[1] This fierce competition inevitably erodes industry profits, threatening production and innovation (Novos and Waldman, 1984; Strauss, 2013; Raustiala and Springman, 2012).

The content and software industry reacted to this threat in several ways, some of them more successful than others. Initially, content producer firms lobbied governments to use all their means to stop piracy.[2] It seemed reasonable to think that the only way to compete with piracy was by making the pirated version harder to find, to make it less attractive from consumers' perspective, and more legally risky to consume. However, these measures proved to take time to implement and most of them have been to be neither easy to enforce nor very efficient. Stopping internet piracy has been compared with *"playing the game of Whac-A-Mole: hit one, and*

[1] Total revenue from U.S. music sales and licensing plunged to \$6.3 billion in 2009, according to Forrester Research. In 1999, that revenue figure topped \$14.6 billion (Goldman, 2010).

[2] An example of this is the Stop Online Piracy Act (SOPA), an attempt of the creative industries to convince American legislators to get involved in the legal campaign. The act failed because of the resistance from technology companies and Internet activists.

quickly countless others appear... and the mallet is heavy and slow."[3]

Thus, creators and producers of digital content had to adapt to a new more competitive world where piracy constrained their business opportunities. On top of reacting with prices, innovation in the way they designed and marketed their content seems to have been a successful strategy in a world where some piracy is unavoidable. As Steve Jobs mentioned in the Rolling Stone's 2003 Interview *"we're never going to stop the illegal downloading services, but our message is: let's compete and win."*[4]

This paper focuses on the later point and explores how firms can exploit the timing of the release of content as a way to mitigate the effects of piracy. We develop an analytical model where a monopolist produces a particular good, and it can choose the time at which its product becomes available to consumers. Therefore, in addition to prices, the monopolist also chooses the share of the product it releases at each of two different periods.

In the absence of piracy, the extent to which the product is made available in each period does not affect the firm's profit. The monopolist can either release everything at the beginning, everything at the end, or any combination thereof, without any effect on total profit. Pricing is sufficient as an instrument to extract the monopoly rent from consumers. Different proportions of the product in different periods change optimal prices proportionally, keeping optimal quantities and the price per share unchanged, which results in the same aggregate monopoly profit whatever the release strategy chosen.

In the presence of piracy, the competitive environment changes and the standard monopoly profit is no longer attainable. Interestingly, as opposed to the case without piracy, profit maximization constrained to this alternative competitive environment cannot be attained by setting only the most convenient prices. Even when the copy is offered for free, piracy is not costless for consumers and the way the monopolist decides to release its product plays a key role in profit maximization.

Consistently with the way demand for pirated products has been modelled in the literature (Bae and Choi, 2006; Belleflamme and Peitz, 2014; Piolatto and Schuett, 2012), in our model consumers who pirate the good incur a cost of piracy that is made of two parts. First, a fix component called the "reproduction cost" that refers to the cost in time and in cognitive effort that consumers face when searching online. Second, a variable component called "degradation cost" that refers to a copy being of lower quality than the original product. Then, pricing in the presence of piracy

[3]The New York Times, "Internet Pirates Will Always Win". Aug. 4, 2012.

[4]The Rolling Stone, "Steve Jobs: Rolling Stone's 2003 Interview". Dec. 25, 2003.

is the same as pricing against another firm that offers a product of degraded quality at a price equal to the reproduction cost.

The way consumers value pirated products introduces a trade-off as to the optimal release strategy of the monopolist. On the one hand, the monopolist has an incentive to divide its product and not to offer it "all-at-once". By offering its product in more than one period, the monopolist takes advantage of the positive reproduction cost that forces consumers to pay twice for the same pirated product. Then, piracy becomes costlier and, other things equal, more consumers are willing to buy the original product. This is a consequence of the reproduction cost of piracy, which allows for the possibility of piracy deterrence in one period.

On the other hand, the degradation cost has the effect of increasing the demand for the original product more than proportionally to the demand of the pirated version as more content is released altogether. This result is explained by the fact that an increment in the share the firm offers in a given period increases the net utility that consumers get from consuming the original product more than what they get from the pirated version. As a consequence, a higher share offered by the firm increases the monopolist's market power.

In equilibrium, the monopolist benefits from releasing content in an asymmetric way across periods. By releasing only a small amount of value in one period, the firm is allowed to deter piracy, relying on that it would be worthless for consumers to pay a reproduction piracy cost for a small amount of value. In the other period (always the first one where there is a discount factor), the firm accommodates piracy and charges a price which is constrained by the opportunity costs of piracy.

The result of this model is aligned with the evidence found in the market of movies and TV shows broadcast, the music industry and software. Since the rise of piracy, we observe how the most successful firms were those who gave non-pecuniary strategies a key role in competing. In particular, when there is a discount factor, our model predicts that most of the content is released at once, and the remaining fraction, not worth copying, is released later. This strategy has many analogies in real life examples. For instance, specialised software tools (like Stata, Matlab, or Mathematica) commercialise a functional base version, which can be extended with paid add-ons.[5] The market for TV shows has implemented similar policies (Wallenstein, 2011; Lynch, 2015; Adalian, 2015), like making shorter seasons for their most famous and most pirated shows (Game of Thrones, Breaking Bad, Mad

[5] We consider technical software as a good example because it abstracts from complexities from two-sided markets or network effects, as we do in our model.

Men, Archer, etc.)[6] whose creators and producers, in turn, have shown less concern about the effects of piracy.[7] Also, the music industry agrees that making one 'long-playing album' (or 'LP') a year is no longer enough and the shorter 'extended play' sibling (or 'EP'), on the other hand, makes much more sense and is very much alive (Rodriguez, 2015; Radar Music Videos, 2013).

This paper proceeds as follows. In the next section, we survey the relevant literature. In Section 3 we present a formal model and the monopolist's and consumers' strategies. In Section 4 we focus on optimal pricing and product design without piracy as the benchmark case. In Section 5 we find the optimal pricing with piracy as a function of the share of the product released in each period. In Section 6, we focus on product design and the equilibrium of the game. Finally, in Section 7, we introduce a discount factor and we show it affect our findings.

1.2 Literature Review

A well-developed literature analyses the consequences of piracy on firms' profitability. Similar to our model, when there is no positive effects from the demand side, Johnson (1985) shows that the pirated copy limits the monopoly power of the original supplier, which results in a more competitive market of the good, even when they are differentiated (copies are inferior to originals, but they are also cheaper). The new market structure inevitably reduces monopoly profit if piracy is a real threat, either because the firm reduces its price to avoid the pirated copy being in the market (the firm "deters" piracy), or because the firm responds in such a way that piracy is present in the market (the firm "accommodates" piracy). If piracy is not a real threat, the monopoly is not subject to any restriction and its monopoly profit remain unchanged (piracy is "blockaded"). Also, Belleflamme and Peitz (2014), and Bae and Choi (2006) get the same results considering a model of vertical product differentiation where a single-product monopolist sells to a continuum of heterogeneous consumers. In this setup, the firm's profits also decrease with the availability of digital copies.

In contrast with the negative results of copying drawn from these basic models, there is also a more favorable view of piracy on the industry profit. In cases where the consumption of the good presents externalities, not enforcing copyright protection

[6]Breaking Bad and Mad Men decided to split their last season in two different years. The same is planned for Game of Thrones.

[7]The creator of Breaking Bad says piracy "helped" the show to become popular and increase "brand awareness" (Izundu, 2013). Also, HBO has said that "Game of Thrones" piracy is a compliment (Hibberd, 2013).

may be privately beneficial even without indirect appropriation. Takeyama (2003) shows that in the presence of network externalities, where consumers' willingness to pay increase in the number of users, full enforcement of copyright protection may involve the monopolist selling to all consumers getting lower profits than in the case of no enforcement. Gayer and Shy (2003) find a similar result. Considering a model of horizontal differentiation between the original and the copy, in the presence of strong network effects, the monopolist is better off with the availability of copies.

Piracy may also be beneficial for a monopolist if it provides information to consumers when the product requires some form of experimentation. Peitz and Waelbroeck (2006) show that the negative effect on sales that results for the existence of the pirated copy may be overcompensated by a positive effect due to sampling in a multiproduct environment. Consumers are willing to pay for the product after sampling because the match between product characteristics and buyers' tastes is improved. In the same line of research, Takeyama (2003) analyses how copies that provide information on the quality of a product can solve an adverse selection in models of asymmetric information. Also, Zhang (2002) considers the role of promotion costs and copying in artistic markets. With piracy, the niche artists can distribute their songs using a P2P technology better finding their audiences, while in the world without copies the distribution technology favours artists with a large audience (or stars).

Although these results are important, they focus on the potential beneficial effects of piracy for producers. Our paper deals with the role of the firm to find and implement alternative business models to avoid negative effects of end-user copying when demand is constant.

The closest paper to ours in terms of reshape of content with constant demand is Alvisi et al. (2002) who analyse the case of versioning. In the absence of piracy, the monopolist has no incentive to differentiate its products. However, with piracy the monopolist might instead produce more than one quality, so that differentiation arises as the optimal strategy: one version for a buyer with a high willingness to pay and a second version (a downgraded version) for a buyer with a low willingness to pay. Similar results over quality were found by Cho and Ahn (2010) who show that the presence of piracy induces the firm to choose a lower level of quality of the former and a higher level of quality of the latter relative to decisions made in the absence of piracy.

Our contribution to this literature is that we also tackle the piracy issue from the firm's product design decision but from a novel perspective. We do this by focusing on the releasing strategy of a particular product, when there is no beneficial effect from piracy. On top of the pricing decision, the monopolist might reduce the negative effect of piracy on profit by changing the timing at which its product available to consumers.

1.3 The Model

Consider a two-period model in which consumers arrive at the beginning of the first period only. The monopolist produces a good with a certain quality and it is able to decide which share of the product is available to consumers in every period, $0 \leq \gamma_t \leq 1$, and $\gamma_1 + \gamma_2 = 1$. The firm has the option to release everything at the beginning ($\gamma_1 = 1$), or everything at end ($\gamma_2 = 1$), or any combination thereof ($0 < \gamma_t < 1$). In addition to that, the monopolist also makes the decision on prices at the beginning of the game. Let p_1 and p_2 denote the prices of the product in period one and two, respectively, with production being costless.[8]

As for the demand side, in each period there is a continuum of consumers of mass 1 whose valuation is uniformly distributed on the interval $[0, 1]$. Consumers differ in their valuation of the good, θ_i, which is private information (the monopolist only knows their distribution). Consumers get different utility depending on the share of the product they consume in each period. They get $\gamma_t\theta_i$ consuming the original product in period t. Consumers can obtain the product in two different ways. They can either purchase the good or, alternatively, they can download a pirated copy (when available). In either period, they can always refrain from consuming the good and they can only consume the product offered by the monopolist at that time. [9]

When piracy is available, consumers have the option to get a pirated copy at a cost d,[10] and the product they get is of lower quality, $\beta\gamma_t\theta_i$, where $0 < \beta < 1$. Following Bae and Choi's terminology, d is the "reproduction cost" of piracy, and $(1 - \beta)$ is the "degradation cost" of piracy.[11] Thus, consumers are heterogeneous in terms of the valuation of the quality differential between original and copy, and homogeneous in terms of the piracy cost. We assume that consumers are aware that they are consuming an illegal good when they download it or get the copy.

[8] The zero-marginal-cost assumption merely facilitates the analysis, what is crucial is that the marginal cost of originals does not exceed the marginal cost of copies, which is a reasonable assumption for digital goods.

[9] We are disregarding the possibility that a consumer at the second period consumes the good offered in the first one (or vice-versa).

[10] This is the same for all consumers and it could reflect the cost of searching for a pirated copy, or the expected cost of downloading a malware, etc.

[11] This is a common assumption in the literature. The pirated copy is seen as imperfect substitutes for the original digital product that provides users with a higher level of quality or services.

1.3.1 Consumers' choice

The utility of a consumer indexed by $t \in \{1, 2\}$ is given by

$$u_t = \begin{cases} \gamma_t \theta - p_t \equiv u_{to} & \text{if buys the original} \\ \beta \gamma_t \theta - d \equiv u_{tp} & \text{if gets the copy (when it is available)} \\ 0 & \text{if refrain from consuming} \end{cases}$$

As we mentioned before, the only heterogeneity among consumers is given by θ. Notice that if we let $g = d + (1-\beta)\gamma_t\theta$, then $u_{tp} = \gamma_t\theta - g$, where g is interpreted as the gross pirate cost.

When piracy does not exist, we define the indifferent consumer, θ_t^m, as the one that gets the same utility when it buys than when it does not buy the good. Formally $\gamma_t\theta - p_t = 0$, then

$$\theta_t^m = \frac{p_t}{\gamma_t} \tag{1.1}$$

Then, all consumers with $\theta \geq \theta_t^m \geq 0$ buy the original, and the other ones stay out of the market.

Similarly, when pirated copy is available, we call θ_t^p the consumer who is indifferent between buying the good and getting the copy in period t. Formally, $\gamma_t\theta_t^p - p_t = \beta\gamma_t\theta_t^p - d$ which gives us

$$\theta_t^p = \frac{p_t - d}{\gamma_t (1-\beta)} \tag{1.2}$$

and all consumers with $\theta \geq \theta_t^p \geq 0$ buy the product in period t, conditional on θ_t^p being lower than 1. In addition to θ_t^p, we call $\tilde{\theta}_t$ the consumer who is indifferent between getting the copy and refraining from consuming the good. Formally, $\beta\gamma_t\tilde{\theta}_t - d = 0$ which gives us

$$\tilde{\theta}_t = \frac{d}{\gamma_t \beta} \tag{1.3}$$

Consumers are willing to buy the copy if $\theta > \tilde{\theta}_t \geq 0$ and $\theta < \theta_t^p$. Finally, consumers refrain from consuming the good if $\beta\gamma_t\theta - d < 0$ and $\gamma_t\theta - p < 0$.

Ex-ante, we don't know the relationship between $\tilde{\theta}_t$ and θ_t^p. Whenever $\tilde{\theta}_t < \theta_t^p$, there will be three different types of consumers: those who buy the original, those who pirate the good, and those who don't consume the good at all. On the contrary, if $\tilde{\theta}_t > \theta_t^p$, then no consumer finds optimal to get the pirated copy and consumers either buy the good or refrain from consuming it. It is the case when the price of the original is sufficiently low relatively to the cost of getting the pirated copy.

Whenever $\tilde{\theta}_t > \theta_t^p$, consumers' valuations in period t are not affected neither by the values of p_j nor γ_j, when $j \neq t$, except for the fact that a change in γ_j changes the value of γ_t (and of prices in both periods accordingly).[12] In other words, there is not a strategic decision from the consumers perspective between periods, their decision of consuming in period t only depends on the values of γ and p in period t.

1.3.2 Monopolist's choice

The monopolist's objective is to maximize total profit which are given by the sum of the profits of the two periods,[13]

$$\Pi = p_1 q_1 + p_2 q_2 \tag{1.4}$$

The demand, q_t, depends on the existence or the non-existence of piracy. When the firm does not face any competition we know that there is only one indifferent consumer between buying and not consuming the good. Then, all consumers with a valuation higher than that indifferent consumer will decide to buy the good from the monopolist. On the contrary, those consumers with a private valuation lower that one of the indifferent consumer will refrain from buying the good given that their net utility is negative. This indifferent consumer is the one with the valuation θ_t^m, then demand is given by $q_t = (1 - \theta_t^m) \equiv q_t^m$.

When the pirated copy is available, the indifferent consumer between buying and pirating the good is the one that determines the demand. The valuation of the indifferent consumer is θ_t, and all consumers with a valuation higher than θ_t decide to buy the original good. Then, demand is given by $q_t = (1 - \theta_t) \equiv q_t^o$.

In both cases, the interaction between the two periods is given by γ_t, which shows that increasing the share of the good in any period increases demand and profits in that period but it unambiguously decreases the willingness to pay and profits in the other one (other things equal). When piracy is possible, a change in γ_t affects the demand of the original product in a different way under the existence or the non-existence of piracy. The difference is explained by the fact that, in the presence of piracy, the share of the product released in each period affects not only the consumers' willingness to pay for the original product but also the consumers'

[12]Given our assumption that $\gamma_1 + \gamma_2 = 1$

[13]There is not discount factor.

willingness to get the pirated copy. Then, the optimal choice of γ_t gives to the monopolist one more instrument to fight against piracy.[14]

1.4 Optimal pricing and product design without piracy: a benchmark case

As a benchmark case, we consider a situation where piracy does not exist, and the consumers' only choice is whether to purchase or not.

From the previous section, we know that all consumers with $\theta \geq \theta_t^m$ buy the product in period t, conditional on θ_t^m being higher than zero and lower than one. Then, the monopolist's demand in period t is given by $q_t^m = 1 - \theta_t^m$. Consumers' net utility in period t depends exclusively on their valuation and prices in period t.[15] Their optimal strategy is independent between periods but it is not the case for the monopolist. The monopolist's total profit is

$$\pi^m = p_1 q_1^m + p_2 q_2^m \tag{1.5}$$

where $q_t^m = \left(1 - \frac{p_t}{\gamma_t}\right)$, for all $t = 1, 2$.

Then, on top of prices, the monopolist has to choose the share of the product it offers in each period.

Lemma 1.1. *When piracy does not exist in the market, the monopolist's total profit is independent of the share of the product offered in each period.*

Proof. Differentiating Equation (1.5) with respect to prices we get

$$p_t^m = \frac{\gamma_t}{2} \tag{1.6}$$

Replacing Equation (1.6) in the demand and in the total profit function we get

$$q_t^m = \frac{1}{2} \tag{1.7}$$

and

$$\pi^m = \frac{1}{4} \tag{1.8}$$

both being independent on the value of γ chosen. □

[14]We show how changes in γ modify the monopolist's profit function in Section 1.6

[15]Remember that each consumer decides whether to buy or not in the second period whatever they did in the first period, and viceversa.

This result is quite intuitive.[16] When there is no competition in the market, optimal monopoly quantities remain the same whatever γ_t chosen. Prices change linearly with γ_t: a rise in γ_2 will increase prices in the second period in the same magnitude as it decreases in the first period. However, the price per share (defined as the price over the share offered in that period) remains constant. As a result, monopoly profit is independent on γ_t, which makes the monopolist indifferent about which share distribution of the product it offers in each period.

1.5 Optimal pricing with piracy

We now introduce the possibility that consumers get a pirated copy of the original good. By getting the pirated copy, consumers save the price of the original but they face another additional cost. Recalling the definition of gross pirate cost

$$g_t = d + (1-\beta)\,\gamma_t\theta \tag{1.9}$$

we observe that piracy entails two types of costs. The first term is the "reproduction cost" (d), that is the cost of getting the pirated copy, and it is the same for all consumers and for any t.[17] The second term is the cost associated with "quality degradation" $(1-\beta)$ because the copy is not a perfect substitute for the original. In our model, consumers are homogeneous regarding the first type of cost, but they are heterogeneous concerning the second one. The monopolist can modify the degradation cost by changing γ_t, which means that the optimal choice of γ_t does affect not only the valuation of the good but also the cost of getting the pirated copy. An increment in the value of γ_t increases consumers' valuation for both, the original good and the pirated copy. However, the increase in consumers' valuation for the latest is lower than the one for the original good, due to the degradation cost. The change in γ_t does not affect the reproduction cost.

The fact that the monopolist can modify the gross cost of piracy through γ_t plays a major role in this model given that the monopolist's strategy influences the existence of piracy not only through prices but also through the share of the product offered in each period.

There is a case in which piracy, even when it is technically feasible, is not a real threat for the monopolist given that the pirated copy is not attractive to any consumer. In this case, and the monopolist is not constraint to offer the monopoly quantity at the monopoly price. This condition arises when the structural barriers

[16]The monopolist produces a scalable product.

[17]It refers to the cost in time and in cognitive effort that consumers face when searching online.

that limit competition (poor quality of the copy or high cost of getting the pirated version) are high in relation to the value consumers get from the pirated copy. Then piracy is said to be *blockaded*, even when it might require the intervention of the monopolist (through γ_t).

Lemma 1.2. *For values of γ_t sufficiently low, $\gamma_t < \frac{2d}{\beta}$, piracy is blockaded in the market at period t.*

Proof. In the absence of piracy, and from Section 1.4, we know that monopoly quantity is equal to $q_t^m = (1 - \theta_t^m) = \frac{1}{2}$. Then, whenever $\tilde{\theta}_t > \frac{1}{2}$, piracy is blockaded in the market. Recalling that $0 \leq \gamma_t \leq 1$, and using Equation (1.3), we get the result. $\square$

Lemma 1.2 tell us that there is always a place for the monopolist to blockade piracy at period t. When piracy is blockaded, price and quantity are the ones obtained in Section 1.4. Notice that if the relative cost of piracy, d/β, is sufficiently high, piracy is blockaded without the intervention of the monopolist. Nevertheless, to have a meaningful analysis of piracy, we restrict our attention to the parameter regions in which the monopolist behaviour is restricted by piracy, that is $\frac{d}{\beta} < \frac{1}{2}$.[18]

The novelty in this model is that the monopolist can limit competition at period t using two different instruments, p_t and γ_t. The use of a limit price is well known in the literature, and it does not present any additional flavour in our model: even when it is a two-period model, the pricing decision at time t only depends on the parameters at time t. However, the decision on γ_t affects the market in period j (where $j \neq t$), given that a higher share of the product offered today necessarily means a lower share tomorrow, that affects demand and prices in both periods.

For the sake of a better understanding of the model, we will first study the monopolist's best response under the piracy regime and the limit pricing regime, keeping γ_t fixed. We will find the similarities with other static models of piracy in the literature where the only variable the monopolist can affect is the price. Then, we focus on the optimal product design and the equilibrium of the game.

1.5.1 Limit pricing regime

As we mentioned above, we first study the monopolist's pricing decision in each period, keeping the share of the product fixed. In this case, the monopolist decides to set a price such that the pirated copy is not attractive for any consumer. In

[18]Later, in Section 1.6, we use a stronger assumption on $\frac{d}{\beta}$ to make piracy exists in at least one period.

this framework, consumers either buy the original or refrain from consuming the good. The price that limits piracy is the one that satisfies the condition $\theta_t^p = \tilde{\theta}_t$ (see Figure 1.1), that is

$$p_t^l = \frac{d}{\beta} \tag{1.10}$$

When the monopolist sets $p_t = p_t^l$, demand[19] and profit at period t are equal to

$$q_t^l = \left(1 - \frac{d}{\gamma_t \beta}\right) \tag{1.11}$$

$$\pi_t^l = \frac{d}{\beta}\left(1 - \frac{d}{\gamma_t \beta}\right) \tag{1.12}$$

We can observe that the limit price is independent of γ_t, but quantities are not. A higher γ_t results in a higher demand and higher profit at period t. However, at the other period, demand and profit are necessarily lower.

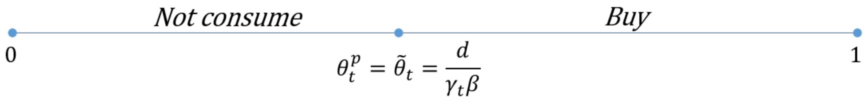


Figure 1.1: Consumers' choice under limit pricing regime, $p_t^l = \frac{d}{\beta}$.

1.5.2 Piracy regime and price setting

The second alternative for the monopolist is to set a price under which piracy is attractive for some consumers ($\tilde{\theta}_t < \theta_t^p$). Then, conditional on the existence of copies, the demand for originals is $q_t^o = 1 - \theta_t^p$, and the optimal price results from maximizing

$$\pi_t^o = p_t \left(1 - \frac{p_t - d}{\gamma_t (1 - \beta)}\right) \tag{1.13}$$

from where we get

$$p_t^o = \frac{1}{2}\left(d + \gamma_t (1 - \beta)\right) \tag{1.14}$$

$$q_t^o = \frac{1}{2}\left(1 + \frac{d}{\gamma_t (1 - \beta)}\right) \tag{1.15}$$

The response of the optimal price to a change in γ_t is the expected one. A higher value of γ_t increases demand and it affects the optimal price positively. A

[19] Given by $q_t^l = \left(1 - \tilde{\theta}_t\right)$

surprising result is the one that comes from optimal quantities: a higher demand reduces the supply of originals. The intuition from this result can be found in the monopolist's pricing behaviour. If there were no price change, a rise in γ_t would lead to some consumers switching from the pirated copy to the original good, which unambiguously increases monopoly profit. However, the monopolist's best strategy is to increase the optimal price which not only eliminates the incentives to switch from the pirated copy to the original good but it also diminishes the base of buyers.

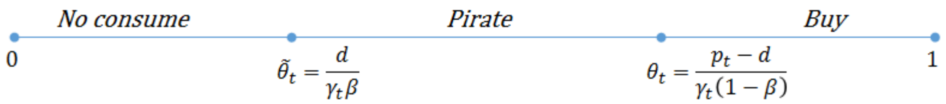


Figure 1.2: Consumers' choice under piracy regime, $p_t^o = \frac{1}{2}\left(d + \gamma_t\left(1-\beta\right)\right) > p_t^l$.

Given the assumptions on the relative cost of piracy, piracy cannot be fully deterred (piracy cannot be deterred in both periods). Then, the decision of the monopolist is to either accommodate piracy in both periods or deter piracy in one of them. In the next section, we show that partial deterrence is the regime that prevails in equilibrium.

1.6 Product design and equilibrium

In this section, we determine the monopolist's best response function when it chooses the product design, i.e. when it can decide the share of the product it offers in each period, γ_t. From the previous section, we have optimal prices and quantities depending on γ_t. Then, the monopolist's objective is to

$$\underset{\gamma_1,\gamma_2}{max} \Pi = \sum_{t=1}^{2} p_t q_t \tag{1.16}$$

$$\text{subject to } \sum_{t=1}^{2} \gamma_t = 1$$

There are different solutions to be evaluated given that piracy might be deterred at period t either using p_t or γ_t. From our results in the previous section, we know that a rise in γ_t increases consumers' willingness to pay in period t which makes the monopolist better off in that period, but it reduces consumers' willingness to pay and monopoly profit in the other one. When the monopolist does not face competition, this trade-off does not play any role on monopoly profit (Lemma 1.1). However, in the presence of piracy, it does play a role because a change in γ_t modifies both, consumers' willingness to pay for the original product and consumers' willingness to get the pirated copy. In other words, the monopolist can limit the effects of piracy by only changing γ_t, when prices remain unchanged.

With the aim to focus on the monopolist's decision over γ_t, we need to restrict the parameters of the model that can affect by themselves the optimal solution. As we showed in the previous section, the parameter that can affect by itself the monopolist's optimal strategy is the relative cost of piracy, $\frac{d}{\beta}$.

Assumption 1.1. *The relative cost of piracy is lower than* $r \equiv \frac{(1-\beta)}{2(2-\beta)}$ *to ensure that piracy always exists in, at least, one of the periods.*

This assumption ensures that whatever the values of γ_t, the monopolist can never get entirely rid of piracy in both periods. Then, the decision of the monopolist is either to accommodate piracy in both periods or to deter piracy in one of them.

When $\frac{d}{\beta}$ is sufficiently close to r, the only level of γ_t at which piracy is present in both markets is at $\gamma_t = \frac{1}{2}$.[20] For example, a small rise in γ_2, makes piracy be still present in period two but completely disappeared in period one. The monopolist would be deterring piracy in the first period not only using prices but also using γ_1. Recalling the effect of a change in γ_t, when the value of the product decreases, the original is relatively more attractive than the pirated copy that, in turn, it becomes relatively more expensive than originals.

As $\frac{d}{\beta}$ decreases, it is harder for the monopolist to deter piracy using γ_t given that, when piracy is cheap, the monopolist has to be much more aggressive in the use of γ_t to make originals more attractive than pirated copies. Then, we can define the limits on γ_t under which piracy is present in both periods.

Lemma 1.3. *Piracy arises in both periods whenever* $\gamma_t \in \left[\gamma_t^L, \gamma_t^H\right]$, *where* $\gamma_t^L = 1 - \gamma_t^H$ *and* $\gamma_t^H = 1 - \frac{d}{\beta}\frac{(2-\beta)}{(1-\beta)}$.

Proof. The monopolist's and consumers' optimal strategies are symmetric in both periods. Assumption 1.1 tells us that piracy arises equally in both periods, which means that $\widetilde{\theta}_t \leq \theta_t^p$ for $t = 1, 2$. We also know that higher values of γ_t reduce θ_t^p and increases $\widetilde{\theta}_t$, which in turn bring them closer to each other. Then, piracy arises in period t, i.e. $\widetilde{\theta}_t \leq \theta_t^p$, whenever

$$\gamma_t \geq \gamma_t^L \equiv \frac{d}{\beta}\frac{(2-\beta)}{(1-\beta)}$$

[20] Assumption 1.1 can be interpreted as the maximum level of the relative cost of piracy that supports piracy simultaneously in both markets.

By symmetry, piracy arises in period j whenever $\gamma_j \geq \gamma_j^L$, i.e. $\gamma_t \leq \gamma_t^H = 1 - \gamma_t^L$. These two conditions give us the limits on γ_t: any $\gamma_t \in \left[\gamma_t^L, \gamma_t^H\right]$ will make piracy exist in both periods. □

The interval in which piracy is present in both periods is wider as d/β decreases, reflecting that deterrence requires more asymmetry in the shares offered when piracy is relatively cheap.[21]

The last result defines two possible equilibrium outputs: either the monopolist chooses γ_t in this interval, or either it chooses γ_t out of it. In the first case, the monopolist accommodates piracy in both periods. In the second one, piracy is deterred in one period and accommodated in the other one. Given that the monopolist's profit function changes for different intervals of γ_t,[22] we have to deal with both scenarios separately. We proceed as follows. First, we present the monopolist's profit function and its optimal decision on γ_t, conditional on $\gamma_t \in \left[\gamma_t^L, \gamma_t^H\right]$, that is, the monopolist offers almost similar shares of the product in both periods. Second, we proceed to find the monopolist's profit function and its optimal decision on γ_t, conditional on γ_t being out of this range, that is, the monopolist offers the total product in two quite asymmetric parts. Finally, we compare both solutions and we get the equilibrium of this game.

1.6.1 Accommodating piracy

We start our analysis by showing the monopolist's best strategy when it accommodates piracy in both periods, in other words, when it chooses $\gamma_t \in \left[\gamma_t^L, \gamma_t^H\right]$. In this case, monopoly prices and quantities in both periods are given by Equations (1.14) and (1.15), and its profit function is

$$\Pi^I \equiv \Pi_{\gamma_t \in \left[\gamma_t^L, \gamma_t^H\right]} = \sum_{t=1}^{2} p_t^o \times q_t^o$$

that is

$$\Pi^I = \sum_{t=1}^{2} \frac{1}{2} \left(d + \gamma_t (1-\beta)\right) \times \frac{1}{2} \left(1 + \frac{d}{\gamma_t (1-\beta)}\right) \tag{1.17}$$

The optimal γ_t is given by maximizing Equation (1.17), subject to $\gamma_t \in \left[\gamma_t^L, \gamma_t^H\right]$ and $\sum_{t=1}^{2} \gamma_t = 1$. The solution to this problem is presented in Proposition 1.1.

[21]However, we will see next that high asymmetry might result in different optimal strategies for the monopolist.

[22]This are the intervals delimited by corner solution.

Proposition 1.1. *The monopolist's optimal strategy is to choose either the minimum or the maximum value in the interval* $\gamma_t \in \left[\gamma_t^L, \gamma_t^H\right]$*, that is either* $\gamma_t^* = \gamma_t^L$ *or* $\gamma_t^* = \gamma_t^H$*.*

Proof. Replacing $\gamma_j = 1 - \gamma_t$, the function to maximizes is reduced to

$$\Pi^I \equiv \tfrac{1}{2}\left(d + \gamma_t\left(1-\beta\right)\right) \times \tfrac{1}{2}\left(1 + \tfrac{d}{\gamma_t(1-\beta)}\right) + \tfrac{1}{2}\left(d + \left(1-\gamma_t\right)\left(1-\beta\right)\right) \times \tfrac{1}{2}\left(1 + \tfrac{d}{(1-\gamma_t)(1-\beta)}\right) \quad (1.18)$$

for any $t = 1, 2$. Maximizing Π^I with respect to γ_t we get the following first order condition

$$\frac{\partial \Pi^I}{\partial \gamma_t} = -\frac{d^2(1 - 2(1-\gamma_t))}{4\gamma_t^2(1-\beta)(1-\gamma_t)^2} = 0 \quad (1.19)$$

which gives us a critical point at $\gamma_t = \gamma_j = \frac{1}{2}$. Then, differentiating Π^I twice with respect to γ_t we get

$$\frac{\partial^2 \Pi^I}{\partial \gamma_t^2} = -\frac{d^2(-1 + 3(1-\gamma_t)\gamma_t)}{2(1-\gamma_t)^3(1-\beta)\gamma_t^3} > 0 \quad (1.20)$$

in the interval $\left[\gamma_t^L, \gamma_t^H\right]$ given the value of the parameters in our model.

Then, the function Π^I is convex and attains a minimum at $\gamma_t = \gamma_j = \frac{1}{2}$. Given that $\gamma_t^L < \frac{1}{2}$ and $\gamma_t^H > \frac{1}{2}$, an interior solution in the interval $\left[\gamma_t^L, \gamma_t^H\right]$ is never optimal. □

If the monopolists wanted to accommodate piracy in both periods, he could offer the original product in two equal shares or in different shares with small asymmetries. As we discussed in Lemma 1.3, the degree of asymmetries under which piracy exists in both periods depends on the relative cost of piracy. Nevertheless, Proposition 1.1 tells us that, conditional on accommodating piracy in both periods, the worst thing the monopolist can do is to offer a product divided into two equal shares.

The intuition of this result is the following. Let's assume that the monopolist starts offering the product in equal shares, $\gamma_1 = \gamma_2$. If it decides to increase γ_2 from $\gamma_2 = \frac{1}{2}$ to $\gamma_2' > \frac{1}{2}$ several things happen. First, a higher value of γ_2 increases consumers' valuation in the second period which induces more consumers to enter the market. However, these consumers are the ones with the lowest valuation who find profitable to consume the pirated version but not the original one. Second, at the same price, some consumers switch from the pirated copy to the original product. This switch is explained by the fact that the valuation of the original product increases in the same proportion with γ_2, but the valuation for the pirated version increases in a lower proportion, $(1-\beta)$. Other things equal, the monopolist is unambiguously better off in that period, even when he does not change its pricing strategy.

Third, in response to higher demand, the monopolist might increase the price to extract more surplus from those consumers who were already buying the original product, in other words, increase the price just to maintain the same price per share and base of consumers.[23] If it were the case, total monopoly profit would not change given that quantities are the same and the price per share in each period remains constant. Nevertheless, there is an additional effect that says that the monopolist can do better than that. A rise in γ_2 makes demand in the second period more inelastic (the opposite happen in period one). As a result, the monopolist has more market power in the period where consumers' valuation is the highest, which calls the monopolist to increase the price even further, ending up with a higher price per share and lower optimal quantities in the second period. The gains in the profit in the second period more than offset the loss in the first one, and total monopoly profit is unambiguously higher.

As a result, when facing piracy in both periods, the best action the monopolist can take is to maximize total quantities, $q_1 + q_2$, which is attained by maximizing the difference between consumers' valuation in both periods. The monopolist's total profit is maximized when it maximizes market penetration (or minimize piracy) in the first period which, simultaneously, skims off the cream in the second one.

1.6.2 Deterring piracy

Now, our aim is to find the monopolist's best strategy when it chooses $\gamma_t \leq \gamma_t^L$ or, similarly, $\gamma_t^H \geq \gamma_t$. As previously mentioned, choosing γ_t out of the range $\left[\gamma_t^L, \gamma_t^H\right]$ means that piracy is deterred in one of the two periods. We are going to differentiate two types of deterrence, that depend on the value of γ_t, which result in two different optimal strategies for the monopolist.

The first type of deterrence happens when, even when piracy is absent at period t, it still conditions the monopolist's behaviour (over prices or quantities). That is the case when $\tilde{\theta}_t < \theta_t^m$, this is the case when γ_t is higher than γ_t^H, but it is not too high. The second type of deterrence happens when, at period t, the valuation of consumers and the monopoly price are so low that piracy does not condition the monopolist anymore, that is the case when $\theta_t^m < \tilde{\theta}_t$ that happens when γ_t is close to one.

[23] Exactly the opposite happens in the first period, where the reduction of γ_1 reduces the total size of the market, the monopolist's demand, and the optimal price.

We need to find the thresholds, $\bar{\gamma_t}^H$ and $\bar{\gamma_t}^L$, under which these two types of deterrence exist. Given the nature of our model, our solution is symmetric which means that, without loss of generality, we can find the threshold for $\bar{\gamma_t}^L$, and $\bar{\gamma_t}^H = \left(1 - \bar{\gamma_t}^L\right)$. Then $\bar{\gamma_t}^L$ is the one that solves

$$\tilde{\theta}_t = \theta_t^m$$

From Section 1.4 we know that $\theta_t^m = \frac{1}{2}$, then

$$\frac{d}{\bar{\gamma_t}^L \beta} = \frac{1}{2}$$

$$\bar{\gamma_t}^L = \frac{2d}{\beta} \tag{1.21}$$

We can now present the monopolist's optimal strategies under the two types of deterrence. For simplicity, we present our results for $\bar{\gamma_t}^L < \gamma_t < \gamma_t^L$ and $0 \leq \gamma_t \leq \bar{\gamma_t}^L$.

1.6.2.1 Conditional deterrence

We present the case where piracy is deterred at period t but still conditions the monopolist's behaviour (over prices or quantities). The monopolist offers a low share of the product at period t (a high share in period $j \neq t$) which causes that the pirated copy is no attractive in that period anymore (even when the price of the original is low, demand is lower too). The monopolist set the limit pricing in that period (Equation 1.10), as long as this price is lower than the monopoly price, $p_t^l \leq p_t^m$.

Lemma 1.4. *At the value of γ_t where piracy starts being deterred, $\gamma_t = \gamma_t^L$, the limit pricing, $p_t^l = \frac{d}{\beta}$, is always lower than the monopoly price.*

Proof. Given that p_t^m is decreasing in γ_t, we only need to show that $p^l < p_1^m$ when $\gamma_t = \gamma_t^L$, that is $\frac{d}{\beta} < \frac{\gamma_t^L}{2}$. This is always true under the assumption that $\beta < 1$ and $d > 0$. $\square$

This is a common result in the literature, in order to deter piracy, the monopolist has to set a price lower than the monopoly price which means that market penetration of the original product is increased (q_t^l defined in Equation 1.11 is higher than q_t^m). When $\gamma_t < \gamma_t^L$, $\theta_t^p < \tilde{\theta}_t$ but θ_t^p is an indifferent consumer that does not longer exist because piracy is already deterred (see Equation 1.2). Then, there are two possible things the monopolist can do, either it keeps $p_t = p_t^l$ and reduces demand according to the decrease in γ_t, or it keeps the same demand and reduces prices accordingly.

Lemma 1.5. *Whenever $\bar{\gamma}_t{}^L < \gamma_t \leq \gamma_t^L$, monopoly quantity in period t is given by $q_t^l = \left(1 - \tilde{\theta}_t\right)$.*

Proof. From $\gamma_t = \gamma_t^L$ backwards, the monopolist can either keep the same price in period t, $p_t = p_t^l$, and reduce demand such that $q_t^l = 1 - \frac{d}{\gamma_t \beta}$, or it can maintain its supply $q_t = 1 - \frac{d}{\gamma_t^L \beta} \equiv q_t^L$, reducing prices accordingly, $p_t = \frac{\gamma_t}{\gamma_t^L} \frac{d}{\beta} \equiv p_t^L$. Then, comparing both alternatives we find that

$$\Pi_{\left(p_t^l, q_t^l\right)} = \frac{d}{\beta}\left(1 - \frac{d}{\gamma_t \beta}\right) > \left(\frac{\gamma_t d}{\gamma_t^L \beta}\right)\left(1 - \frac{d}{\gamma_t^L \beta}\right) = \Pi_{\left(p_t^L, q_t^L\right)}$$

which is always true under the condition that $\bar{\gamma}_t{}^L < \gamma_t \leq \gamma_t^L$. □

When $\theta_t^p < \tilde{\theta}_t < \frac{1}{2}$, the monopolist can deter piracy in period t using two different instruments, p_t or γ_t. Lemma 1.5 shows that the monopolist's best strategy is to keep the same limit pricing as γ_t falls, provided that $\theta_t^p < \tilde{\theta}_t$. This strategy ends up reducing market penetration in both periods. This is the result of its optimal deterring strategy, where the indifferent consumer between pirating and not consuming the good is the one that determines the demand for the original product, who is no sensitive to a price change.

Having defined the monopolist's optimal deterrence strategy, we can now focus on its product design when $\gamma_t \in \left(\bar{\gamma}_t{}^L, \gamma_t^L\right)$. The monopolist's profit function is

$$\Pi^{II} \equiv \Pi_{\gamma_t \in \left(\bar{\gamma}_t{}^L, \gamma_t^L\right)} = p_t^l \times q_t^l + p_j^o \times q_j^o$$

for $j \neq t$. That is

$$\Pi^{II} = p_t^l\left(1 - \frac{d}{\gamma_t \beta}\right) + p_j^o\left(1 - \frac{p_j^o - d}{\gamma_j\left(1 - \beta\right)}\right) \tag{1.22}$$

and $\gamma_t + \gamma_j = 1$. The optimal γ_t is derive from maximizing Equation 1.22 with respect to γ_t, subject to $\gamma_t \in \left(\bar{\gamma}_t{}^L, \gamma_t^L\right)$ and $\gamma_t + \gamma_j = 1$. The solution to this maximization problem is presented in Proposition 1.2.

Proposition 1.2. *The monopolist's optimal strategy in the interval $\gamma_t \in \left(\bar{\gamma}_t{}^L, \gamma_t^L\right)$ is given by γ_t^{**}, that is interior and unique.*

Proof. Replacing $\gamma_j = 1 - \gamma_t$, Equation 1.22 is reduced to

$$\Pi^{II} = \frac{d}{\beta}\left(1 - \frac{d}{\gamma_t \beta}\right) + \frac{1}{4}\left(d + \left(1 - \gamma_t\right)\left(1 - \beta\right)\right)\left(1 + \frac{d}{\left(1 - \gamma_t\right)\left(1 - \beta\right)}\right). \tag{1.23}$$

Maximizing Π^{II} with respect to γ_t we get the following first order condition

$$\frac{\partial \Pi^{II}}{\partial \gamma_t} = \frac{1}{4}\left(\beta + \frac{4d^2}{\beta^2\gamma^2} + \frac{d^2}{(1-\beta)(1-\gamma)^2} - 1\right) = 0 \tag{1.24}$$

that is a polynomial of degree 4. However, in the relevant interval the solution is unique (root 2), given that neither of the other 3 solutions satisfy the restriction $\bar{\gamma}_t{}^L < \gamma_t < \gamma_t^L$ (root 1, $\gamma_t < 0$, root 3, $\gamma_t > \frac{1}{2}$, and root 4, $\gamma_t > 1$). Even when the profit function is not concave for all the parameter values, we know that the solution found, γ_t^{**}, is a maximum because the profit function is strictly monotone increasing in the interval $\gamma_t \in \left(\bar{\gamma}_t{}^L, \gamma_t^{**}\right)$, and strictly monotone decreasing in the interval $\gamma_t \in \left(\gamma_t^{**}, \gamma_t^L\right)$, which also tells us that the solution is interior. □

As explained above, from the point where piracy starts being deterred in period t ($\gamma_t = \gamma_t^L$ and backwards), the monopolist faces a more costly trade-off than in the case of small asymmetries: it still continues skimming off the cream in period j, but market penetration in period t is also reduced as γ_t decreases (Lemma 1.5). Monopoly profit increases in period $j \neq t$ at the expense of also reducing optimal quantities in period t. In the beginning, the total effect on monopoly profit is still positive, given that the gain in period j more than offset the loss in period t. However, from γ_t^{**} backwards, the gain obtained in the period with the higher demand does not compensate the loss of consumers in the period where consumers' willingness to pay is lower. At this point, there is nothing else the monopolist can do to avoid losing market penetration in period t given that demand is independent of prices.

1.6.2.2 Unconditional deterrence

It remains to find the optimal strategy for extreme values of γ_t, when the monopolist offers very different shares of its product in both periods, $0 \leq \gamma_t \leq \bar{\gamma}_t{}^L$. At the extreme, it is the case where the monopolist offers "all-at-once" in one of the two periods. When $\gamma_t = \bar{\gamma}_t{}^L$, the monopolist's optimal quantities are equal to the monopoly quantity when piracy does not exist, given that $\bar{\gamma}_t{}^L$ is defined where $\widetilde{\theta}_t = \theta_t^m = \frac{1}{2}$, which also means that $p_t^m = \frac{\bar{\gamma}_t{}^L}{2} = \frac{d}{\beta} = p_t^l$.

Lemma 1.6. *Whenever* $0 \leq \gamma_t \leq \bar{\gamma}_t{}^L$*, the monopolist's optimal quantities are given by* $q_t^m = \frac{1}{2}$.

Proof. From $\gamma_t = \bar{\gamma}_t{}^L$ backwards, the monopolist can either maintain the same limit price in the first period, $p_t = p_t^l$, which means reducing demand and the price per share as γ_t decreases, $q_t^l = 1 - \frac{d}{\gamma_t\beta}$, or it can maintain its supply ($q_t^m = \frac{1}{2}$) and the price per share, reducing prices accordingly, $p_t^m = \frac{\gamma_t}{2}$. Then, comparing both alternatives we find that

$$\Pi_{(p_t^l, q_t^l)} = p_t^l \left(1 - \frac{d}{\gamma_t \beta}\right) < \left(\frac{\gamma_j}{2}\right) \frac{1}{2} = \Pi_{(p_t^m, q_t^m)}$$

which is always true under the condition that $0 \leq \gamma_t \leq \bar{\gamma_t}^L$. □

As γ_t decreases, the monopolist's optimal deterrence strategy is to supply the monopoly quantity in the first period while reducing p_t. This result is quite intuitive and equivalent to the result we get in the simple monopoly case: any deviation from the monopoly quantity makes the monopolist worse off. In contrast to what we found in Lemma 1.5, that the optimal strategy to deter piracy meant reducing quantities maintaining the limit price, here we find that the monopolist is better off doing the opposite in period t. Then, the total profit is

$$\Pi^{III} \equiv \Pi_{\gamma_t \in [0, \bar{\gamma_t}^L]} = p_t^m \times q_t^m + p_j^o \times q_j^o$$

for $j \neq t$. That is

$$\Pi^{III} \equiv \frac{\gamma_t}{4} + p_j^o \left(1 - \frac{p_j^o - d}{\gamma_j (1 - \beta)}\right) \tag{1.25}$$

and $\gamma_t + \gamma_j = 1$.

Again, the optimal product design, γ_t, is given by maximizing Equation 1.25, subject to $0 \leq \gamma_t \leq \bar{\gamma_t}^L$ and and $\gamma_t + \gamma_j = 1$. The solution to this problem is presented in Proposition 1.3.

Proposition 1.3. *The monopolist's optimal strategy is to choose the maximum level of γ_t in the interval $\left[0, \bar{\gamma_t}^L\right]$, that is $\gamma_t^{***} = \bar{\gamma_t}^L$.*

Proof. Replacing $\gamma_j = 1 - \gamma_t$, Equation 1.25 is reduced to

$$\Pi^{III} \equiv \frac{\gamma_t}{4} + \frac{1}{4} \left(d + (1 - \gamma_t)(1 - \beta)\right) \left(1 + \frac{d}{(1 - \gamma_t)(1 - \beta)}\right) \tag{1.26}$$

Deriving Π^{III} with respect to γ_t we get

$$\frac{\partial \Pi^{III}}{\partial \gamma_t} = \frac{1}{4} \left(\beta + \frac{d^2}{(1 - \gamma_t)^2 (1 - \beta)}\right) \tag{1.27}$$

that is increasing with γ_t in the interval $\left[0, \bar{\gamma_t}^L\right]$, that is, the optimal value in the interval $\left[0, \bar{\gamma_t}^L\right]$ is $\gamma_t^{***} = \bar{\gamma_t}^L$.

□

The intuition is the following. Similar to the case where $\gamma_t \in \left(\bar{\gamma_t}^L, \gamma_t^L\right)$, the monopolist faces a trade-off by setting $\gamma_t < \bar{\gamma_t}^L$: it increases the profit in period $j \neq t$ at the expense of decreasing the profit in period t. However, as opposed to what happen in that case, piracy is blockaded at period t. The loss of profits in period t that results after decreasing γ_t is higher than the rise in profits generated in period j, which means that the monopolist's best strategy in that interval, is to set the maximum value of γ_t, this is $\gamma_t^{***} = \bar{\gamma_t}^L$.

Now, summing up the results presented in Propositions 1.1, 1.2, and 1.3, we are ready to present our main result.

Theorem 1.1. *The monopolist's optimal strategy is to release its product in two shares of difference sizes which, in turn, results in deterring piracy in one of those periods. The "all-at-once" releasing strategy is always the worst response.*

Proof. Altogether, Equations 1.17, 1.22, and 1.25 determine the monopolist's total profit function that is symmetric in $\gamma_t = \frac{1}{2}$. When the difference in the size of the shares is small, i.e. piracy is accommodated in both periods, the monopolist's profit function is convex and attains a minimum at $\gamma_t = \frac{1}{2}$, which says the the monopolist's optimal strategy is to maximize the difference in the size of the shares as much as possible.

Next, with stronger asymmetries, we have two different cases. The first case is when piracy is deterred but it still conditions the monopolist's behaviour. Given the symmetry of the game, we have two solutions given by γ_t^{**} and $(1 - \gamma_t^{**})$. The second one is when the share the monopolist offers in one of the periods is so low that piracy does not condition the monopolist behaviour anymore. In this case, the best strategy for the monopolist is to offer the maximum possible share in the period with the lowest demand, conditional on piracy being blockaded, to take advantage of the positive fixed cost of piracy.

In order to show that γ_t^{**} found in Proposition 1.2 is the solution of our game when $\gamma_t < \frac{1}{2}$,[24] we only need to show that our profit function is continuous in γ_t, which is the case given that both conditions

$$\Pi^{I}_{\gamma_t \to \gamma_t^L} = \Pi^{II}_{\gamma_t = \gamma_t^L}$$

and

$$\Pi^{II}_{\gamma_t \to \bar{\gamma_t}^L} = \Pi^{III}_{\gamma_t = \bar{\gamma_t}^L}$$

[24]The other solution is $(1 - \gamma_t^{**})$ when $\gamma_t \geq \frac{1}{2}$

are true. In addition, $\Pi^{III}_{\gamma_t=0}$ (and $\Pi^{III}_{\gamma_t=1}$) is the minimum value of the monopolist's total profit function because the monopolists does not use in his favour the possibility of duplicating the fixed cost of piracy to consumers, which makes it worse off.

□

Theorem 1.1 says that even when the monopolist is unable to hinder piracy increasing its cost (either by increasing the cost of getting the pirated copy, d, or by decreasing the quality of the copy, β) it can better compete with it by changing the timing at which it makes its product available to consumers. By doing this, it can take advantage of the positive fixed cost of piracy, and its effect on the demand elasticity, making competition harder to the pirated copy, which results in piracy being deterred in one of the markets. Similarly to the findings of Bae and Choi (2006), the extent to which originals are used can be complementary with the extent of piracy, compared to our benchmark case. The intuition for this result can be found in the monopolist's pricing behaviour in response to the threat of piracy: the price reduction not only eliminates the incentives to switch for the consumers of the pirated copy to originals, but it also expands the base of total buyers which results in higher total profit.

Figure 1.3: Monopolist's total profit function for $\gamma_t \in [0, 1]$

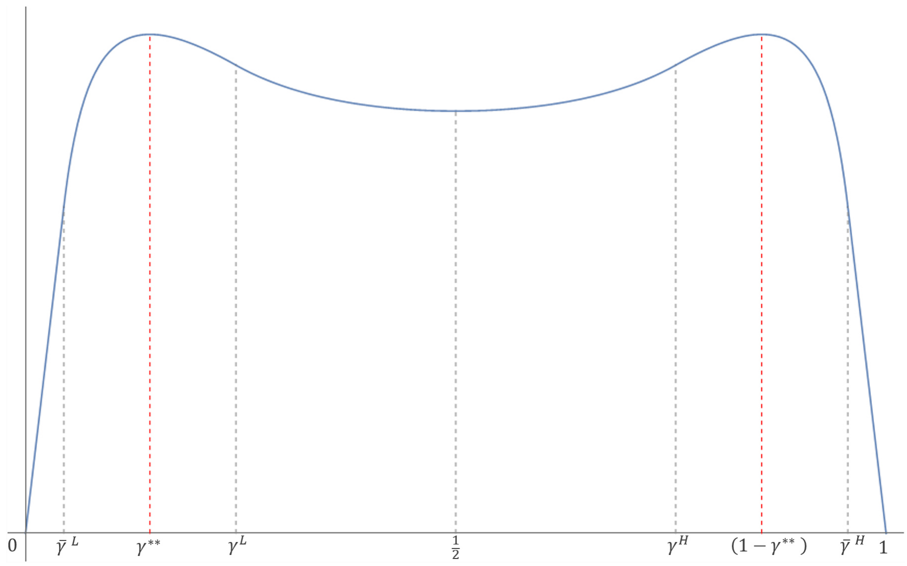


Figure 1.3 shows the monopolist's total profit function plotted for all the support of γ_t (the profit function is a mirror image in $\gamma_t = \frac{1}{2}$). As previously explained for $0 \leq \gamma_t \leq \frac{1}{2}$, we use the symmetry of our model by showing the behaviour of the profit function from $\gamma_t = \frac{1}{2}$ onwards. We can see that the profit function is first increasing in γ_t, meaning that the rise in consumers' valuation in period t more

than offset their decrease in demand in period $j \neq t$. Then, as consumers' valuation and prices go up in period t, piracy becomes less attractive in period j where, at current prices, all demand is supplied by the monopolist ($\gamma_j = \gamma_j^L$ and $\gamma_t = \gamma_t^H$). The monopolist's best strategy is to maximizes market penetration (or minimize piracy) in period j, that simultaneously skims off the cream in period t. From that point onwards, an increase in γ_t reduces market penetration in the period j that, at the same price, reduces even more the monopolist's profit in period j. Then, the monopolist's continues increasing γ_t up to the point where its marginal benefit in period t is equal to its marginal cost in period j ($\gamma_t = 1 - \gamma_t^{**}$).

As opposed to our benchmark case (where piracy does not exist and γ_t does not play any role on total profit), the way the monopolist decides to release its product plays a key role in profit maximization. The monopolist has now a clear reason to not offer "all-at-once". Even when the copy is offered for free, piracy is not costless for consumers and, by offering its product in more than one period, the monopolist takes advantage of the positive reproduction cost that forces consumers to pay twice for the same pirated product. Moreover, in equilibrium, the monopolist benefits from releasing content in an asymmetric way across periods. By releasing only a small amount of value in one period, the firm is allowed to deter piracy, relying on that it would be worthless for consumers to pay a reproduction piracy cost for a small amount of value. In the other period, the firm accommodates piracy and charges a price which is constrained by the opportunity costs of piracy.

1.7 Extension: Discount Factor

We now show how the result of our model changes when we introduce a discount factor. The monopolist's maximization problem (Equation 1.16) changes to

$$\underset{\gamma_1,\gamma_2}{max} \Pi = p_1 q_1 + \delta p_2 q_2 \tag{1.28}$$

subject to

$$\gamma_1 + \gamma_2 = 1$$

$$\delta \leq 1$$

When δ is lower than one, the symmetry of our model does not hold anymore. In fact, we show that there is a unique solution in which the share offered in the first period is higher than in the second one. Moreover, the effect of the discount factor could be strong enough to make the "all-at-once" option the monopolist's best strategy.

Proposition 1.4. *There exists a threshold, $\tilde{\delta} \in [0, 1]$, such that as δ decreases, the monopolist best strategy is to increase the share of the product offered in the first period, whenever $\delta \geq \tilde{\delta}$. Otherwise, when $\delta < \tilde{\delta}$, the monopolist's optimal strategy is to offer "all-at-once" in the first period.*

Proof. See Appendix A. □

In the interval $\delta \in [\tilde{\delta}, 1]$ the monopolist maintains the same strategy: it accommodates piracy in the first period (where it offers the highest share), and deters piracy in the second one. It means that its profit is given by Equation 1.22 that becomes

$$\Pi_{\delta}^{II} \equiv p_1^o \left(1 - \frac{p_1^o - d}{\gamma_1 (1 - \beta)}\right) + \delta p_2^l \left(1 - \frac{d}{\gamma_2 \beta}\right)$$

Starting from an equilibrium point, a decrease in δ in the interval $[\tilde{\delta}, 1]$, erodes monopolist's profit in the second period. The monopolist's best response is to offer a higher share of the product in the first period to compensate the loss in profits in the second one, which means that γ_2^{**} is reduced.

When $\delta = \tilde{\delta}$, the monopolist is indifferent about releasing "all-at-once" in the first period than the positive amount $\tilde{\gamma_2}$ in the second one (defined in the Appendix A). We also know from Proposition 1.4 that $\tilde{\gamma_2} \in \left[\bar{\gamma_2}^L, \gamma_2^L\right]$.

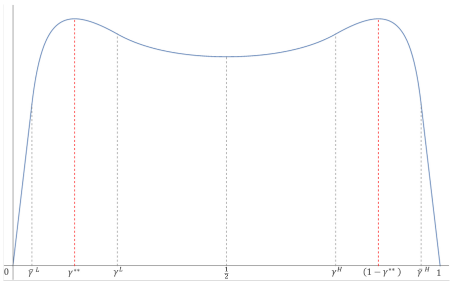
Then, $\tilde{\gamma_2}$ can be interpreted as a "fixed cost" for the monopolist: any value of γ_2 chosen between zero and $\tilde{\gamma_2}$ is never a best response. There is a minimum share that needs to be released in the second period to make this strategy profitable from the monopolist perspective. Even when it can make use of his ability to duplicate the reproduction cost to consumers by releasing a positive share in the second period, the profits it gets from doing that might not compensate the loss in profits in the first period if the discount factor is sufficiently low.

In comparison with our benchmark case, when piracy exists in the market the interaction between the first and the second period is also different when $\delta < 1$.

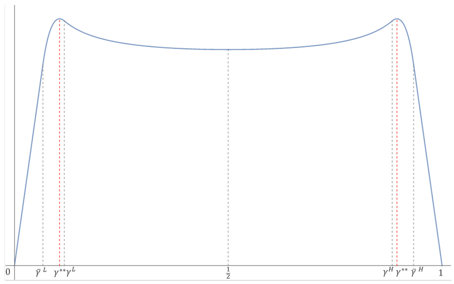
When piracy is not an issue, any value of δ lower than one, induces the monopolist to offer "all-at-once" (that is the weakly dominant strategy $\forall\delta$). There is no gain of postponing content to the second period. However, when piracy is a real threat, the strategy of releasing everything at the beginning is optimal only if the discount factor is sufficiently low, $\delta < \tilde{\delta}$. For higher values of δ, $\delta > \tilde{\delta}$, the monopolist refrains from doing so, given that its best strategy is to postpone some content to the second period to benefit from partial deterrence.

In Figure 1.4 we present the monopolist's profit function for some values of δ and β (d is fixed). The left panel shows how the profit function changes as δ decreases,

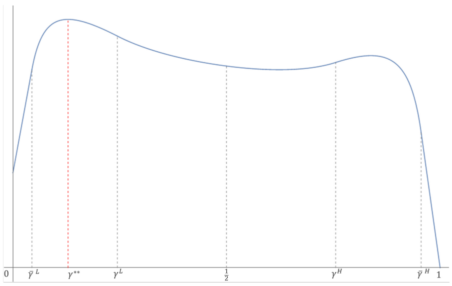
Figure 1.4: The monopolist's total profit for different values of δ and β.



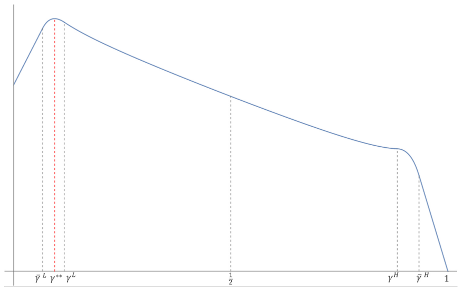
(a) $\delta = 1$ when $\beta = 0.9$ and $d = 0.02$



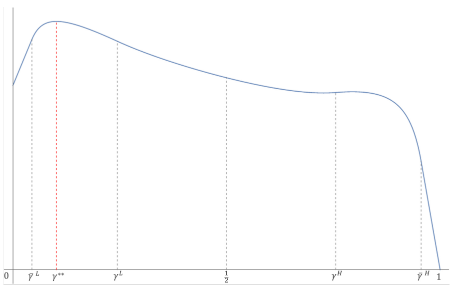
(b) $\delta = 1$ when $\beta = 0.6$ and $d = 0.02$



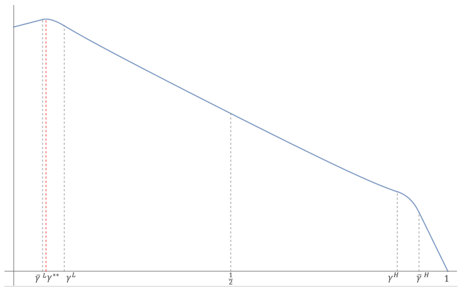
(c) $\delta = 0.8$ when $\beta = 0.9$ and $d = 0.02$



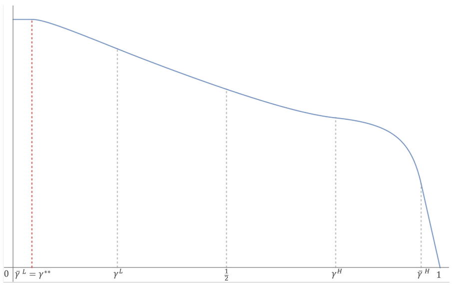
(d) $\delta = 0.8$ when $\beta = 0.6$ and $d = 0.02$



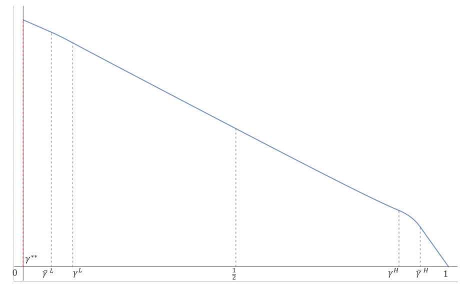
(e) $\delta = 0.5$ when $\beta = 0.9$ and $d = 0.02$



(f) $\delta = 0.5$ when $\beta = 0.6$ and $d = 0.02$



(g) $\delta = 0.1$ when $\beta = 0.9$ and $d = 0.02$



(h) $\delta = 0.1$ when $\beta = 0.6$ and $d = 0.02$

for a small degradation cost ($\beta = 0.9$), while the left one shows how it changes when the degradation cost is higher ($\beta = 0.6$). The first thing we notice is that when β is lower, the range of γ_2 under which piracy is accommodated is higher (and the range of deterrence is lower). On the one hand, a rise in β makes piracy less attractive from consumers' perspective facilitating deterrence. However, on the other side, it also reduces competition and increases the monopolist's total profit which give to it fewer incentives to deter piracy in the first place.

Second, when δ is low ($\delta = 0.1$), the monopolist has incentives to release "all-at-once" in the first period when the degradation cost is higher in comparison with a lower degradation cost. This result is because, with a high degradation, the monopolist faces weaker competition from piracy in a single period, which makes it easier to deter and to get higher profits in the first period.

1.8 Conclusions

Online piracy has become popular by satisfying the public's demands for fast, cheap, and easy-to-access entertainment. Since it started, it has been a contentious issue and, year after year, it gets more clever and elusive.

Making the pirated version harder to find and more legally risky to consume has shown to be most effective way to reduce piracy, although its final effect is of little significance.

We present a model in which the private firm is the one that by changing its business model changes consumers' incentives towards buying the original product. We showed that, in the absence of piracy, the product availability in each period does not affect the firm's profit. The monopolist might either release everything at the beginning, everything at the end, or any combination thereof, and its profit is independent of the way in which content is released.

However, in the presence of piracy, the way the monopolist releases its product does affect its profit. Even in the case where there is no "positive effect" from the demand side, the firm can reduce the adverse effect of piracy by changing the timing it makes its product available to consumers. Then, on top of prices, the monopolist has another instrument to fight against piracy, that is the releasing strategy. This optimal strategy gives the monopolist the possibility of increasing its total profit. In equilibrium, the firm is always better off releasing positive but asymmetric shares of its product in both periods.

Finally, we show that, if there exist a low discount factor, the strategy of releasing "all-at-once" might be the best one, even when it is never the best approach in the case with no discount factor. The idea is that the monopolist needs to release a minimum share in the second period to make it profitable and, when the discount factor is low, the future profits might not compensate the losses of reducing the value of the product today.

Chapter 2

Shill bidding in common value auctions with discrete information

2.1 Introduction

In auction literature the strategy of cheating by placing anonymous bids on the sellers behalf to artificially drive up the prices of the auctioned item is known as *Shill bidding*. Shill bidding occurs in second-price auctions like English and Vickrey auctions where the seller, or his agent, pretends to push up the price the winner pays without the consent of the auctioneer. The key element for getting benefits of cheating is the anonymity of the virtual bidder, the seller.

Our aim in this paper is to build a simple model of shill bidding in an English pure-common value auction. We choose this environment to show, in the one hand, how the seller updates his shill bid as the auction goes on. In the other hand, we show how this bid updating process affects the legitimate bidders' perception of the common value of the object. We find that, even in the extreme case where bidders are fully myopic, the seller might be worse off doing shill bidding.

When shill bidding is used in a private value context, the goal of the seller is to place a bid in between the second and the first highest bid in order to increase the price the winner pays. Nonetheless, when placing a bid the seller does not know if this bid is in fact in between the two highest bids. On the contrary, in common value auction, even when the seller does not find profitable to submit a bid higher than the legitimate second highest bid, his participation change the bidders' perception of the common value of the object which may result in a higher selling price.

Moreover, in static auctions, shill bidding is a one-shot decision for the seller: at the beginning of the auction he has to decide if he submits a shill bid or not based on the expected gain he get in each of both cases. However, in dynamic auctions the seller is able to update his optimal shill bid as the auction goes along. This "flexibility effect" makes us think the strategy of shill bidding as a dynamic reserve price which should give the seller at least the same profits as in the static case.

In our model, given that bidders are fully myopic, they interpret the seller's behavior as private information coming from a legitimate bidder and they update their beliefs about the common value of the object, that might result in bidding more aggressively than in an auction without this strategy. For this to happen, the seller must send a high signal. This is not an issue when the seller can decide to drop out at any price: the seller will be active until two remaining bidders are in the auction and he will decide to drop out immediately or to wait a bit longer depending on the actual price of the object. This is almost always the case when bidders' valuations come from a continuous distribution and drop out prices are accepted at any time during the auction.

However, when bidders' valuation come from a discrete distribution and the participants are only able to drop out at particular announced prices, the seller faces a higher cost of being active in the auction at higher prices: the future announced price could be to late for him, and he could find himself a winner with a high probability.

Our model shows how this discreteness affects the seller's expected gain of shill bidding. In the one hand, he wants to send the highest possible signal to buyers. In the other hand, being active in the auction (even at very low prices) does never reduce to zero the probability of wining his own object. The seller might be worse off doing shill bidding since the probability of ties in a discrete case increase the probability of winning the object which, in turn, reduces the expected gain of participating in the auction. Then, when the number of signals and possible drop out prices is small, the seller might be better off refraining from participating in the auction. This is the case when his valuation is sufficiently low in comparison with bidders' valuation or when the number of legitimate bidders is sufficiently high.

The intuition of this result is that, for a given seller's valuation and a number of legitimate bidders, a small number of signals (and drop out prices) increases the probability of ties and the seller's expected probability of finding himself a winner, for any given price. Then, the decision of dropping out at a low price can be very costly for the seller's perspective such that he finds that the best option is to stay out of the auction. This cost is reduced as the number of remaining bidders in a certain stage increases (the expected probability of wining the object is reduced), and/or as the seller's valuation is closer to the legitimate bidders' valuation (the cost of wining the object is also reduced). However, the shill bid has an upper bound above which it is never profitable whatever the number of remaining bidders or participants in the auction.

Finally, we show that, similarly to an optimal reserve price, the optimal shill bidding strategy is not immune to the number of participants in the auction and that if the number of bidders is sufficiently high then the seller is always better off refraining from participating.

The paper is organized as follows: in Section 2.2 we survey the relevant literature. We present the formal model of common values, the payoffs and the strategies, and the timing of the game in Section 2.3. In Section 2.4 we show how the auction works in absence of shill bidding, while in Section 2.5 we present the model with shill bidding and the main results. Finally, we conclude in Section 2.6 and in Section 2.7 with some final remarks and conclusions.

2.2 Literature Review

Even though the term "shill bidding" became recently popular with the spread of online auction, the concept exists since long time ago. The book written by Cassady (1967) had a major influence among auction theorists. He describes how real-life auctions work and this topic appears in various chapters of this book, even when he does not use this specific term. He defines a "puffer" as a "person who, without having any intention to purchase, is employed by the seller at an auction to raise the price by fictitious bids, ... while he himself is secured from risk by a secret understanding with the seller that he shall not be bound by his bids".

More recently, Lamy (2009) showed that the possibility of shill bidding changes the ranking of auctions stated in the linkage principle introduced by Milgrom and Weber (1982). He shows that when the seller is not able to commit to not participate in the auction the linkage principle does not hold. The second price auction's performance is strictly deteriorated by the shill bidding activity and rational bidders but, on the contrary, the first price auction is immune to shill bidding. He gets that, under certain assumptions, the shill bidding effect can outweigh the benefits of conveying information. However, if bidders are not aware of this cheating, the seller is always better off submitting a shill bid.

Vincent (1995) had previously presented a mechanism with a similar motivation to the one in Lamy's paper. He found that in a common value auction a seller with a random reservation value can increase her ex ante expected profits by following a policy of secret reserve price compared to an auction in which the reserve price is announced. The idea is that the announcement of a reserve price may have an *inhibiting effect* on bidders' participation in a given auction discouraging some bidders from participating. The consequence is that a sale could not be made even though the aggregate information would imply that a transaction should occur.

Thus, in different ways, both Vincent's and Lamy's papers studied the effects of shill bidding in sealed bid second price auctions and they conclude that the seller is always better off doing shill bidding if bidders are not aware of it. The intuition is quite simple: placing a bid in the gap in between the reserve price and the lowest legitimate bid, the seller can increase his expected payoff.[1] This is possible either because shill bidding is not penalized or because, even being penalized, the seller can place any bid without being detected. [2] In static auctions, Vincent's secret reserve price is equivalent to the concept of shill bidding in Lamy's paper. Anyway, in dynamic auctions, these concepts are not equivalent any more.

Chakraborty and Kosmopoulou (2004) were the only ones, to the best of our knowledge, that used an ascending auction to study the effects of shill bidding. However, given the nature of the model they used, the flexibility effect does not appear. They consider the effect of shill bidding in a common value auction using a two signal model. Given there exist a reserve price that is in between both signals, the seller's strategy of shill bidding is, again, a one-shot decision.

Our contribution in this paper is to fill a gap that we think is missing in the literature. In the one hand, we consider shill bidding in a setting where bidders' private information comes from a discrete distribution of signals. In the other hand, we use a three signal model with no reserve price (absolute auction) in order to understand the dynamics on the seller's incentives to shill bid in an English auction.

2.3 The Model

In this section we first lay out the basic model of pure common value auction, we describe a number of conditions on the model that are useful for the subsequent analysis, and then we present the equilibrium bidding strategies and expected revenue formulas for the standard auction without and with shill bidding, respectively.

We consider the following pure common value auction model. There are n risk neutral bidders in an English auction for a single object. There is a common valuation for the object and each bidder has partial information or an estimate about

[1] Although Lamy also tried to analyzed the ascending auction, he only gave the intuition that, given the flexibility effect, the seller's expected gain in a second price auction serves as a lower bound of the seller's profits in the dynamic case.

[2] In a fully rational world, a common value auction with shill bidding cannot be better than an auction with commitment from the seller's point of view. For more details about this statement see Chakraborty and Kosmopoulou (2004), and Lamy (2009).

the common value. Let s^i, $\forall i = 1, ..., l$, be the private signal of bidder i. We assume that s^i can take three different values, $s^i \in \{s_1, s_2, s_3\}$, which are equally probable and equally distanced between each other such that $s_1 < s_2 < s_3$.[3] The signals also have the feature that the lowest and the highest signal are equal to the lower and to the upper bound of the signal distribution $[\underline{s}, \overline{s}]$, respectively. Summing up, we have that $s_1 = \underline{s}$, $s_2 = s_1 + \triangle$, and $s_3 = s_2 + \triangle = \overline{s}$, which give us $s^i \in \left\{\underline{s}, \frac{(\overline{s}-\underline{s})}{2} + \underline{s}, \overline{s}\right\}$. This information is commonly known by all the players in the game, the bidders and the seller.

The common value of the object is defined as the average of legitimate bidders' signals:

$$V = \frac{1}{n} \sum_{i=1}^{n} s^i$$

where n is the number of legitimate bidders in the auction. Notice that there are no efficiency issues in pure common value auctions as all bidders place equal value on the item.[4]

The seller's value is $v_0 = 0$, and it does not affect the bidders' valuation. Also, there is not reserve price (we will see later how the results of the model change when the seller can set an optimal reserve price).

2.3.1 The Auction

The English auction takes place in the following way. First, the auctioneer sets the price at zero and gradually raises it. As it is an open auction, the price is observed by everyone. Bidders signal their willingness to buy by raising a hand, holding up a sign. This action of every bidder is witnessed by all, so at any time the set of active bidders is commonly known. Bidders, who are symmetric, might drop out at any time, but once they do this they cannot reenter the auction at a higher price. If the auction ends with two or more bidders dropping out at the same price (i.e., there is a tie) the item is allocated at random, the winner pays the last drop-out price, and the seller receives this amount (there is not commission fee to the auctioneer).

If there is only one bidder in the auction the object is not sold in that auction.

2.3.2 Bidders' strategies

The common value of the object, V, is unknown (ex-ante) and belongs in the interval $[\underline{s}, \overline{s}]$. We focus on the symmetric equilibrium of an ascending auction in which

[3]We will also call s_1, s_2, and s_3 as the low, medium, and high signal, respectively.

[4]Efficiency becomes an issue if the seller decides to set an optimal reserve price.

each bidder plays his weakly dominant strategy: they drop out when they are just indifferent about finding themselves a winner or not.

Given the discreteness of our model, each signal identifies an optimal drop-out price. Furthermore, regardless those prices, they are identical for any bidder who receives the same signal. Thus, we can identified ex-ante three stages in the auction where: 1) bidders with s_1 drop out, 2) bidders with s_2 drop out, and 3) bidders with s_3 drop out.[5]

The first drop out is at a price equal to the signal of the lowest bidder(s) since that would be the actual value of the object if all bidders had that signal. At that price, several things can happen. First, if all bidders drop out at that price, the winner is chosen at random among all of them. Second, if all bidders drop out at that price but one, that remaining bidder is the winner of the auction. In both previous cases the winner pays the same drop-out price. Finally, if there are more than one remaining bidder at the end of that stage, the auction goes on up to the next stage of the game and the new drop-out price is updated with the information recently acquired.

Let j_1 be the number of bidders who are competing in the first stage of the auction, j_2 be the number of bidders who are competing in the second stage of the auction, and j_3 is the number of bidders who are competing in the third stage of the auction. Notice that j_1 is not the number of bidder who have a signal equal to s_1, but the number of bidders who have a signal at least equal to s_1. Given that there is not reserve price that inhibits players to participate in the auction, we get $l = j_1 \geq j_2 \geq j_3$, where l is the number of participants in the auction.

The undominant strategy is given by

$$b^i\left(s^i\right) = \frac{1}{l}\begin{cases} s_1 & \text{if } s^i = s_1 \\ \left[s_1\left(j_1 - j_2\right) + s_2 j_2\right] & \text{if } s^i = s_2 \\ \left[s_1\left(j_1 - j_2\right) + s_2\left(j_2 - j_3\right) + s_3 j_3\right] & \text{if } s^i = s_3 \end{cases}$$

which is our discrete three-signals form of the symmetric equilibrium strategies in an English auction.[6][7]

[5] Notice that the value of the signals are ex-ante commonly known reducing our problem to estimating the expected number of bidder who drop out at each stage of the auction.

[6] See Krishna (2009) for more details.

[7] This is an undominanted strategy because an unilateral deviation gives the seller the same utility. As an example, assume that all but one bidder drop out in the first stage of the game and the remaining bidder decides to continue active in the auction even when he also received the lowest signal. Then, the remaining bidder wins the object and he pays exactly the value of the lowest signal, his valuation. If he had played the undominated strategy describe above, he would have been tied with l bidders and he would have won the object with probability $\frac{1}{l}$, paying exactly

Notice that bidders' strategies depends on l, the number of participants, but their common valuation depend on n, the number of legitimate bidders and their signals. This difference, in addition with Assumption 2.1, is what can make shill bidding profitable to the seller in our model.

Assumption 2.1. *Bidders are "myopic" in the sense that they put zero probability that a fake bidder is participating in the auction.*

Bidders do observe the number of participants in the auction, l , and they always believe that $l = n$. In other words, they put zero probability on the event that a fake bidder is participating in the auction. The seller's participation does not only distort the bidders' strategy because there is one more bidder, but also because this bidder is sending a fake signal that might affect the perception of the real common value of the object.[8] We will come back to this issue in Section 4, up to now what is important is to have in mind that l is equal to n if only legitimate bidders are bidding in the auction, and $l = n + 1$ otherwise.

In order to set an example of how this optimal bidding strategy works, imagine an auction where the first drop-out price is at $p_1 = s_1$, without loss of generality. If at the end of this stage there are at least two remaining bidders, in other words if $j_2 \geq 2$, it means that the signals of those remaining bidders should be either s_2 or s_3. Then, if the next highest bidder has a signal equal to s_2, the next drop-out price is at $p_2 = {}^1\!/_l \left[s_1 (j_1 - j_2) + s_2 j_2\right]$, which is the price at which a bidder with the medium signal is indifferent about finding himself a winner or not. If $j_3 \geq 2$, there are also bidders who have the highest signal and they compete for the object at the third stage of the auction. In that case, the next drop-out price is at $p_3 = \frac{1}{l} \left[s_1 (j_1 - j_2) + s_2 (j_2 - j_3) + s_3 j_3\right]$. In any case, if at the end of the first or the second stage there is only one remaining bidder in the auction, that remaining bidder is the winner of the object and he pays a price strictly lower than his perceived valuation (it is the only case in which the winner can get some information rent).

If at the end of the first stage the next highest bidder has a signal equal to s_3, then no bidder drops out at the second stage of the game and the next drop-out price is at $p_3 = {}^1\!/_l \left[s_1 (j_1 - j_2) + s_3 j_3\right]$, given that $j_2 = j_3$. Furthermore, it is also the final price of the object given that s_3 is the highest possible signal and $j_2 = j_3 = l - j_1$.

We use a simple example to show that this is the bidders' optimal strategy in the symmetric equilibrium. Suppose there are four bidders in the auction, $s^i \in \{1, 2, 3\} \, \forall i = 1, ..., 4$, and the signals of each bidder are $S = \{1, 2, 2, 3\}$. The weakly

his valuation. In both cases, the seller ends up with zero surplus. Given that we are interested in symmetric equilibrium, we assume that players use this undominated strategy.

[8]Notice that the common value only depends on the legitimate bidders' signals.

dominant strategy says that bidders with the lowest signal should drop out at $p_1 = 1$. The remaining bidders take this information and use it to update the new drop-out price which is equal to $p_2 = \frac{7}{4}$. From that price on there would be only one remaining bidder in the auction who wins the object at a price p_2.

Suppose now that the bidder who has the lowest signal wants to bid as a bidder with a medium signal. Then, given he does not know the other bidders' signals but he observe no one drops out $p_1 = 1$, two things can happen. First, if the highest bidder does not drop out at the second drop-out price (which is the case in our example), then it means that our bidder does not win the object at $p_2 = 2$ and his payoff is the same as if he had dropped out at a price p_1 (but in that case p_2 would have been equal to $\frac{7}{4}$). Second, if he finds himself the winner at a price $p_2 = 2$ (it would be the case if $S = \{1, 2, 2, 2\}$ and he is the random winning bidder), then he pays a price higher than the common value of the object $v = \frac{7}{4}$, and he ends up loosing $\frac{1}{4}$. Thus, the strategy calls for each bidder to continue until the price is such that if he were to win the object at that price he would just break even.

It is important to notice that when the lowest bidder drops out, he knows the other bidder's signals are at least as high as his own signal. This means that when he quits he knows that the value of the object is at least the price at which he drops out. So the question is, why does he drop out when he knows the value of the object is weakly higher? This situation occurs because the bidder is avoiding what is commonly known as *the winner's curse.* The idea behind this strategy is that the relevant thing to bidder i is not the expected value of the object, but its expected value conditional on him winning it. Something similar happens to the bidder who wins the object. If he wins the object he knows that all the other signals were below his own signal and, to avoid paying more for the object and regret after this, he must adjust the value of the object on him winning it.

2.3.3 Seller's strategy

The seller has a value $v_0 = 0$. The aim of the seller is to sell this object at the higher price, however, he knows that auctioning the object the winner bidder will pay the second highest price (given there is not optimal reserve price).

The seller is not allowed to bid on his own object. However, because he wants to make the informational rent as small as possible, he might have incentives to enter the auction pretending to be a legitimate bidder with the aim to push the price the winner pays. This practice is known as *shill bidding* and it is forbidden by the auctioneer because it forces legitimate bidders to pay more than they should or more than the true market value of the object.

There are two countervailing incentives the seller faces when he decides to shill bid. In the one hand, there exists *the price effect*, given that the shill bid might change the price of the object by being the second highest bid. This effect is present in whatever kind of auction the object is being sold. However, this price effect has a particular component in interdependent values auction (where the common value auction is an special case). The shill bid might also change the bidders' perception of the common value of the object. We call this effect *the perception effect* and it is an important effect in our model. Comparing the common values case with a simple private values model (Izmalkov, 2004), and under regular conditions, the seller has an extra incentive to stay in the auction until only one legitimate bidder remains, because the more the seller stays active, the higher the perception effect is.

In the other hand, if the seller decides to shill bid he faces the risk of finding himself the winner which is, of course, bad news for him. We call this effect *the probability effect.* Note that this probability effect also includes the probability of ties, that under the assumption of discrete signals, cannot be disregarded.

Following Chakraborty and Kosmopoulou (2004) we suppose the auctioneer does not have the technology to make shill bidding difficult to sellers, but this strategy is penalized. Therefore, we assume that when the seller participates in the auction he bids just like a legitimate bidder would bid in that situation, otherwise he is identified with certainty and penalized.[9] The seller also knows the number of active bidders n before entering the auction.[10]

Conditional on being in the auction, the seller has two countervailing incentives. On the one hand, he will want to send a high signal in order to increase the perception of the common value of the object and, consequently, the final price the winner pays. But on the other hand, we wants to bid as low as possible in order to not win the auction.

Before the auction starts, the seller decides to enter the auction and to shill bid with probability $\mu \in [0, 1]$, which means:

[9]If shill bidding was not penalized, the seller's optimal strategy would be to bid right below the level other legitimate bidders would do. We supposed that if some participant drops out in between two optimal drop-out prices, he is perceived as a bidder with the lowest possible signal. However, this assumption is not enough to guarantee the seller would bid as a legitimate bidder because after observing this drop out it might be too late for the bidders to revise their strategies affecting truthful reporting. Then, we also assume that when observing such drop out, and assuming this bidder has the lowest possible signal, the auctioneer updates the last optimal drop out price and he starts again raising the price from that last updated price.

[10]This assumption can be though as if the seller is in the room where the object is going to be auctioned and decide at the very last minute if the fake bidder (hired by him) participates or not in the auction.

$$\begin{cases} \mu = 1 & \text{if the seller finds profitable the strategy of shill bidding} \\ \mu = 0 & \text{if the seller does not find profitable the strategy of shill bidding} \\ \mu \in (0,1) & \text{if the seller is indifferent between shill bidding or not} \end{cases}$$

If he decides to refrain from participating in the auction, then it takes place normally with n bidders competing for the object. If the seller decides to participate in the auction, at any bidder's drop-out price the seller updates his optimal strategy which is translated into an optimal stopping time.

Assumption 2.2. *The seller is an "advantage bidder" meaning that he has the possibility to drop out at a certain stage once he observed how many bidders have already dropped out at that stage.*

Even when Assumption 2.2 is not reliable, it is useful for practical purposes: it help us to show the dynamics on the seller's decision using the minimum amount of signals. Given that Assumption 2.2 does not change the bidders' optimal strategy, then the seller's revenue of this game is an upper bound on the seller's revenue when all the participants simultaneously decide whether to drop out at a given stage or to continue active in the following stage of the game.

2.3.4 Timing of the game

We present the game in four stages, from zero to three. However, inside these stages there exist sequential decisions (given Assumption 2.2). We call "players" to both kind of participants in this auction, the bidders and the seller. The timing is as follows:

- *Stage 0:* the seller is the only player who has to make an strategic decision. He observes the number of legitimate bidders in the auction, n, and he decides to enter in the auction to shill bid with probability μ, or to stay out with probability $(1-\mu)$. If the seller decides to stay out of the auction, the auction starts with no shill bidder. The bidders don't have to make any strategic decision. They will enter in the auction as long as their value, that ex ante is their own signal, is higher than the reserve price. In view of the fact that there is not reserve price and that the lowest signal is equal to one, all bidders interested in participating in the auction enter it.

- *Stage 1:* once the auction starts, the price rises until it reaches a value equal to the lowest signal, s_1. Here, all the bidders with the the lowest signal drop out.[11] If the seller decided to enter the auction with some probability, after observing how many bidders remain active for the second stage, j_2, he decides to also drop out at this stage or to continue to the second stage of the game. In case there is only one remaining player at the end of this stage, the remaining player is the winner of the object, he pays the drop-out price, and the game is over. If there are more than one remaining player, the auction continues to the second stage.

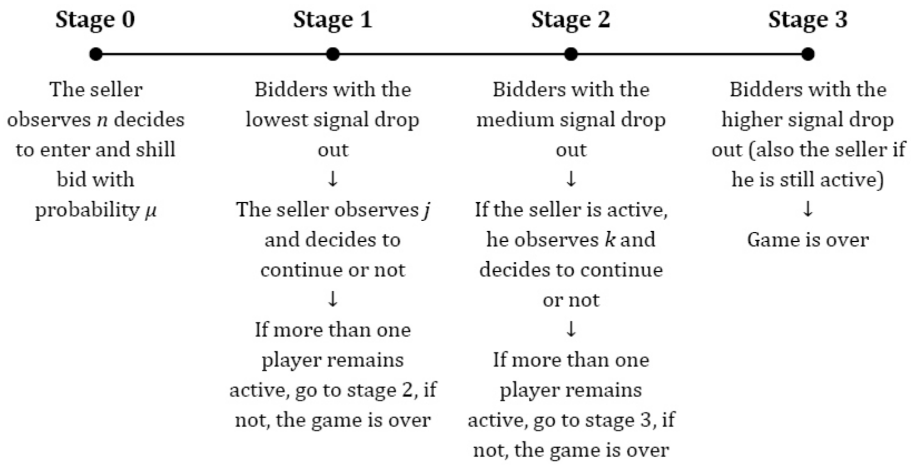
- *Stage 2:* all bidders with a medium signal drop out. The price at which this occur is ex-ante unknown but we know that if we are in this stage of the game the price should be higher than s_1 and at most equal to s_2, more specifically it belongs to the interval $\left[\frac{(l-2)s_1+2s_2}{l}, s_2\right]$. If the seller is active after the bidders with a medium signal drop out, he observes how many bidders remain active to the third stage, j_3, and he decides if he drops out immediately or if he continues to the last stage of the game. In case there is only one remaining player at the end of this stage, the remaining player is the winner of the object, he pays the drop-out price, and the game is over. If there are more than one remaining player the auction continues to the third stage.

- *Stage 3:* all j_2 bidders and the seller (if he is active) drop out. The price in which this occur is ex-ante unknown, but it will belong to the interval $\left[\frac{(l-2)s_1+2s_3}{l}, s_3\right]$.

At every stage of the auction game there are a positive probability of ties that cannot be disregarded. If this is the case, the item is allocated at random between all tied bidders who have the same probability of winning the object. Figure 2.1 sum up the stages of this game.

[11] The first drop-out price is equal to the lowest signal because no bidder drops out before that stage.

Figure 2.1: Timing of the game



2.4 Standard auction without shill bidding

Consider an English auction with $n \geq 2$ legitimate bidders. Bidders are symmetric and they play their weakly dominant strategy. The winner pay to the auctioneer the last drop-out price. In order to simplify the analysis we suppose that there is not commission fee (c) the seller must pay to the auctioneer. If it were the case that the winner was tied with other bidders, the second highest valuation would be equal to the first highest valuation and there would be no information rent for the winner.

Assumption 2.3. *The lower bound of the private information distribution (signal distribution), $\underline{s}$, is weakly higher than the value of the seller, v_0.* In other words, $v_0 = 0 \leq \underline{s}$.

We also use the following assumptions,

Assumption 2.4. *The value of the seller (v_0) does not affect the bidders' valuation.*

Lemma 2.1. *When $n = 2$, the second highest valuation is equal to the second highest signal.*

Proof. With only two bidders in the auction, when the second highest bidder drops out he does not have any information from previous drop-out prices. It means that his best strategy is to drop out when the price is equal to his own signal given that his signal is how much he values the object conditional on him winning it. □

The technical issue we face is that, given the nature of the problem, in a common value auction the second highest valuation, i.e. the price, is equal to the second highest signal only when $n = 2$. For $n > 2$, the second highest valuation is affected by the observed signals of bidders who drop out before the second highest bidder's drop-out price. When $n = 2$ we can focus on calculating the second order statistic of the signals that is equivalent to the second-order statistic of bidders' valuation. However, if $n > 2$ this shortcut is no more valid given that the second-order statistic of bidders' valuation depends on the information collected during the auction.

In continuous case the ex-ante estimation of the second order statistic of bidders' valuation is easily handled. The second highest bidder with signal s^{n-1} is willing to pay anything up to his expected value conditional on him winning the object but being just tied with the winner at the same signal. The issue is that, ex ante, the second highest bidder does not see the other $n-2$ opponents' bids, so we need to estimate those signals using the conditional distribution on them being below s^{n-1}.[12]

In the discrete case the estimation of the second order statistic of bidders' valuation is more complicated given that we cannot disregard the probability of ties. In order to calculate the expected second highest valuation we build a mechanism to get the outcomes of the extensive-form game. We present it in Lemma 2.2.

Lemma 2.2. *The expected second highest valuation of the English auction with $n \geq 2$ legitimate bidders, that it is also the seller's expected gain when he refrains from participating, is given by*

$$\mathbb{E}\left(gain\right)^{no\ shill} = \frac{1}{3^n}\left[\left(1+2n\right)\underline{s} + \sum_{j_2=2}^{j_1}\left(\begin{array}{c} j_1 \\ j_2 \end{array}\right)\left\{f\left(\frac{\sum_{z=1}^{2} j_z}{n}\right)\left[1+j_2\right] + \sum_{j_3=2}^{j_2}\left(\begin{array}{c} j_2 \\ j_3 \end{array}\right)\left\{f\left(\frac{\sum_{j_z=1}^{3} j_z}{n}\right)\right\}\right\}\right] \tag{2.1}$$

where $f\left(x\right) = \frac{(x-1)}{2}\left(\overline{s} - \underline{s}\right) + \underline{s}$, j_i is the number of bidders which are active at stage i (in other words, is the number of remaining bidders at the end of stage $i-1$), and $j_0 = j_1 = n$.

Proof. We calculate the expected second highest valuation in the extensive-form game where $s^i \in \left\{\underline{s}, \frac{(\overline{s}-\underline{s})}{2} + \underline{s}, \overline{s}\right\}$. We first define a function β_i given by

$$\beta_i = \sum_{j_i=g}^{j_{i-1}}\left(\begin{array}{c} j_{i-1} \\ j_i \end{array}\right)\left\{f\left(\frac{\sum_{z=1}^{i} j_z}{n}\right)\left[1 + j_i\left(3-i\right)\right] + \beta_{i+1}\right\} \qquad \forall i \in \{1,2,3\}$$

where

[12] In the case of uniform distribution in an interval $[0,1]$, the estimate of those signals is $\frac{1}{2}s^{n-1}$, since conditional on them being below s^{n-1} they are uniformly distributed below s^{n-1}.

$$\beta_{i>3} = 0$$

$$g = \begin{cases} n & \text{if } i \leq 1 \\ 2 & \text{if } i > 1 \end{cases}$$

First, notice that there exist as many β_i as number of signals in the auction. The sum of the $\beta_i's$ estimate the different final prices times the frequency of these prices in the auction. In particular, the function $f(\cdot)$ calculates the different final prices, given the history of the game.[13] The binomial coefficient and the expression on square brackets estimate the frequency of each of those prices.[14] Finally, β_{i+1} captures the continuation payoffs if the auction reaches stage i but it does not end in stage i. The sum over j_i goes from 2 onwards because is the minimum number of bidders needed in that stage to be played. If there are less than two players, that stage of the game is never reached and the continuation payoff is zero. Moreover, the sum goes up to j_{i-1} because the number of competing bidders cannot exceed the number of remaining bidders in the previous stage, j_{i-1}.[15]

Once we get β_1, β_2, and β_3, we sum up all of them and we divide the sum by the number of total possible cases of the extensive game: for n bidders, all the possible combinations of 3 signals among them are equal to 3^n, and we get

$$\mathbb{E}\left(gain\right)^{\text{no shill}} = \frac{1}{3^n}\sum_{i=1}^{3}\beta_i$$

□

There are two important things to say about Equation 2.1. The first one is that the second highest valuation is increasing in the number of bidders given that our distribution is Increasing Failure Rate (IFR). The second one is that it converges to the mean of the distribution, given the pure-common value assumption. We show both effects in Example 2.1.

Example 2.1. Consider an English auction where the value of the seller is $v_0 = 0$, and the values for the three possible signals are $\{1, 2, 3\}$. The seller's expected gain

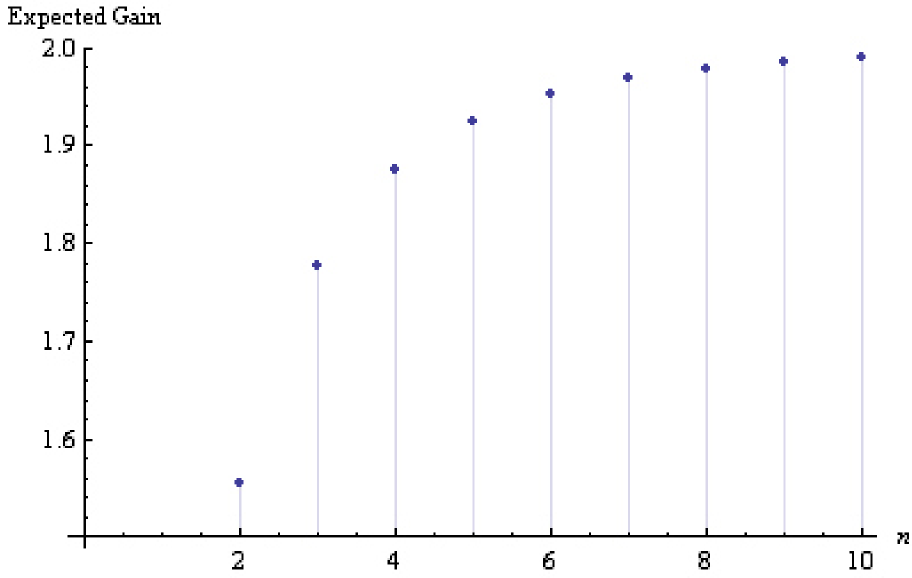
[13] By default, the value of signals are given by the natural numbers without zero. Then, if we have three signals their values are 1, 2 and 3. The function $f(i)$ scales the price for different signal distributions.

[14] Inside the square brackets, the number 1 represents the case where all remaining bidders drop out at stage i, and $j_i(3-i)$ represents the number of cases where all remaining bidders except one drop out at that stage.

[15] In the first stage the sum goes from n to n showing that at the first stage all player are active.

in the auction with no shill bidding and with n bidders is equal to the expected second highest valuation given by Equation 2.1. The expected gain is increasing in the number of bidders and converges to the media of the distribution, 2.

Figure 2.2: Seller's expected gain when he refrains from participating



Now we got the expected gain of the seller when he refrains from participating in the auction and we need to compare it with the expected gain shill bidding. We find the seller's optimal strategy and its expected payoff in the following Section.

2.5 Standard auction with shill bidding

Suppose now that the seller is able to enter the auction and to shill bid in order to increase the perception of the common value of the object and the second highest valuation. Would it be profitable for him? Given that the seller is not able to observe bidders' signals, he must update at each step of the auction if it is profitable for him to continue or to stop.

As previously mentioned, there are two effects that shill bidding can produce:

1. *The probability effect.* This effect reflects the risk the seller faces of finding himself a winner when he decides to enter the auction and shill bid.

2. *The price effect.* The shill bid could change the price of the object by being the second highest bid (*private value effect*), but also by changing the bidders' perception of the common value of the object (*perception effect*).

We will show that the *price effect*, in equilibrium, cannot be negative (otherwise the seller is not behaving optimally). The *probability effect* is a seller's cost and, in absolute terms, it is always non-positive and it is exacerbated by the price effect (they are not independent effects).[16]Notice that even when the seller decides to drop out immediately after the last drop-out price (coming from a legitimate bidder), the seller might be able to increase the price of the object changing the second highest drop-out price through the perception effect. Can the seller do better? It depends on the last drop-out price, on the potential effect on the final price and on the probability of finding himself a winner when he submits that shill bid.

Given this game is a sequential game with finite horizon, we can solve it backwards. However, in the last stage of the game there is no strategic decision for any player: if the last stage is reached, all the legitimate bidders will drop out at that stage and, given that the seller should behave as a real bidder, if he is active in the auction he will also drop out at that stage. Then, we should start solving the game in the second stage of the auction, when bidders with a medium signal drop out. At that moment, the seller has to decide if he drop out at the end of the second stage or if he continues up to the last stage of the game. It is easy to see that this decision of dropping out at a given stage is relevant if and only if there is at least one remaining legitimate bidder at the end of that stage, otherwise the seller is always better of dropping out at the given stage because if he continues to the following stage he finds himself a winner with certainty.

2.5.1 Second stage of the auction

Suppose that the seller is still active in the second stage of this game (where the bidders with a medium signal drop out). The seller has to decide if he also drops out at this stage or if he continues up to the last stage. Without loss of generality, suppose that if the seller drops out at stage 2, the final price of the object is equal to X_2. If the seller decides to continue in the auction, the price of the object would be $X_2 + \varphi_{j_3}$, where φ_{j_3} is the increment the seller produce in the final price of the object after he decide he will be active at the last stage of the game.[17] But the seller

[16]Imagine the situation where the seller decides to be more aggressive in the auction and he continues active one more stage. In that case, he increases the perception of the common value of the object and the second highest valuation, but he also has more chances of finding himself the winner.

[17]The parameter φ_{j_3} can take two values in this setting. If there is only one remaining bidder at the end of the second stage, then $\varphi_{j_3=1} = \frac{2}{n+1}(s_3 - s_2)$. In the case there are more than one remaining bidder in the auction, $\varphi_{j_3>1} = \frac{1}{n+1}(s_3 - s_2)$. The difference comes from the fact that when there is only one remaining bidder in the auction, the decision of continuing in the auction raise the price not only because of the marginal effect the seller produces in the final price of the

receives this price as long as he does not find himself the winner, and this happen with probability $\frac{j_3}{j_3+1}$, where j_3 is the number of bidders at the last stage (or the number of remaining bidders at the end of the second stage). If the seller is still active in the auction at the last stage, his expected income is $\left[(X_2 + \varphi_{j_3}) \frac{j_3}{j_3+1}\right]$. The expected gain of the seller of staying up to the second stage of the auction (rather than remaining active at the third stage) is given by

$$\mathbb{E}\,(gain)^{s_2^*} = X_2 - (X_2 + \varphi_{j_3}) \frac{j_3}{j_3 + 1}$$

which is always negative.

Lemma 2.3. *It is never a best response for the seller to bid as a bidder with the highest signal when $v_0 \leq \underline{s}$.*

Proof. Suppose the seller and more than one bidder are still active at the second stage (where the price is equal to the medium signal), $j_3 \geq 2$. In this case, if the seller decides to drop out at this stage, his profit will be $\frac{\sum s_{\neq j_3} + s_2 + j_3 s_3}{n+1}$, where $\sum s_{\neq j_3}$ is the sum of signals of bidders who are not active in the third stage of the auction. However, if he continue in the auction bidding as a bidder with the highest signal, the price of the object will increase up to $\frac{\sum s_{\neq j_3} + (j_3+1) s_3}{n+1}$, but he has $\frac{1}{j_3+1}$ of chances of find himself the winner, and his expected gain is $\frac{j_3}{j_3+1}\left(\frac{\sum s_{\neq j_3} + (j_3+1) s_3}{n+1}\right)$. The seller's expected gain of bidding as a bidder with the medium signal instead of the higher one is given by

$$\mathbb{E}\,(gain)^{s_2^*}_{j_3=2} = \frac{\frac{1}{2}\left(\overline{s} - \underline{s}\right)(j_3 + 1) + \sum s_{\neq j_3}}{(j_3 + 1)(n + 1)}$$

that is always positive.

Now, suppose that at the second stage there is only one remaining bidder, $j_3 = 1$. Using the same logic expressed above, if the seller bids as a bidder with the highest signal, his expected profit is equal to $\frac{1}{2}\left(\frac{\sum s_{\neq j_3} + 2 s_3}{n+1}\right)$. But if he drops out at the second stage, his profit is $\frac{\sum s_{\neq j_3} + 2 s_2}{n+1}$ for sure. The expected gain of the seller of bidding as a bidder with the medium signal instead of the higher one is given by:

$$\mathbb{E}\,(gain)^{s_2^*}_{j_3=1} = \frac{2\underline{s} + \sum s_{\neq j_3}}{2\,(n + 1)}$$

object, but also because of the marginal effect the remaining bidder also produces on it. In the latter case, if the seller does not continue in the auction, the object is sold at a lower price and the winner enjoys a positive information rent. If the seller decides to continue in the auction, the seller appropriates this rent as long as he does not find himself the winner.

that is also always positive. So, to bid as a bidder with the higher signal is never a best response.

Finally, suppose that by the second stage all bidders drop out. The best response for the seller is to also drop at this stage (if he continue in the auction he wins the object with probability one). In this case, the expected gain is $\frac{j_2}{j_2+1}\left(\frac{\sum s_{\neq j_3}+s_2}{n+1}\right)$.

Summing up, in any possible case when $v_0 \leq \underline{s}$, bidding as a bidder with the highest signal is never a best response for the seller. $\square$

This result is aligned with Lamy's result (2009) where he shows that in an static auction (second price auction) there exist an upper bound of the shill bidding activity above which it is never optimal to shill bid. At the end of the second stage of the game, the seller knows that if he does not drop out immediately he will be tied with the highest bidder in the third stage of the game.

Once we showed that the seller does not find profitable to bid as a bidder with the highest signal we can simplify the general model. Once the shill bidder decides to enter the auction, the strategic decision is either to drop out at the first stage or at the second stage of the game.

2.5.2 First stage of the auction

We know from the previous analysis that, conditional on entering the auction, the seller's optimal decision is either to bid as a bidder with the lowest signal or to bid as a bidder with the medium one. A priori, if he sends the lowest signal he would be minimizing the probability of finding himself the winner but also he would be sending a signal that reduces the expected price of the object compared to the case of staying out of the auction. Then, given Assumption 2.2, the seller can decide at the end of first stage to drop out immediately at that stage or to continue active up to the second stage. We will see that the seller's decision to either drop out at the first or at the second stage of the auction depends on the total number of legitimate bidders, on the number of remaining bidders in the first stage (j_2), and on the signal distribution.

Lemma 2.4. *The seller's expected profit of dropping out at the first stage of the auction, rather than at the second one, is increasing in n but decreasing in j_2. Moreover, this expected profit increases if the signal distribution is sufficiently narrow or far from v_0.*

Proof. The seller's expected gain of dropping out in the second stage when $j_2 = 1$ is given by $\frac{3}{4}\left(X_1 + \varphi_{j_2=1}\right)$, where X_1 would be the price if the seller dropped out at the first stage ($X_1 = \underline{s}$), and $\varphi_{j_2=1} = \frac{2}{n+1}(s_2 - s_1)$. But if the seller drops out at the first stage of the auction, he receives $\underline{s}$ with probability 1. Then, the net expected gain of dropping out at the first stage when there is only one remaining bidder in the auction is given by

$$\mathbb{E}\left(gain\right)_{j_2=1}^{s_1^*} = \underline{s} - \frac{3\overline{s} + 3n\underline{s}}{4\left(1+n\right)} \tag{2.2}$$

This function is monotone and increasing in n (but with decreasing marginal effects). Also, this function might take positive or negative values or both (for different values of n) depending on the the signal distribution. We can easily check that the seller will find incentive to drop out at the first stage if and only if $\underline{s}\left(4+n\right) \geq 3\overline{s}$.

The seller's expected gain of dropping out in the first stage when $j_2 > 1$, is given by

$$\mathbb{E}\left(gain\right)_{j_2>1}^{s_1} = \frac{1}{2^{j_2}}\left\{X_2 - \left[\left(X_2 + \varphi_{j_2>1}\right)\frac{j_2}{j_2+1}\right]\right\} - \frac{2^{j_2}-1}{2^{j_2}}\varphi_{j_2>1}$$

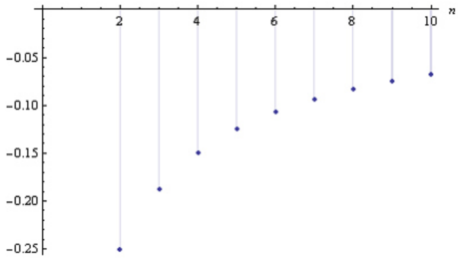
where $\varphi_{j_2>1} = \frac{s_2 - s_1}{n+1}$, and X_2 is the price if the seller dropped out at stage 1 when j_2, the remaining bidders at the end of the first stage, have a signal equal to two, $X_2 = f\left[\frac{n+1+j_2}{n+1}\right] = \frac{j_2(s_3-s_1)}{2(n+1)} + s_1$. The expression in bracket keys reflects the seller's incentives of dropping out in the first stage when j_2 remaining bidders have the medium signal and all of them drop out at the second stage of the auction. This case only happens once out of 2^{j_2} possible combination of remaining signals (s_2 and s_3) among j_2 remaining bidders. In the rest of the cases the seller loses $\varphi_{j_2>1}$ that is the negative effect the seller produces in the perception of the common value of the object given he sent a low signal. This expression can be reduce to

$$\mathbb{E}\left(gain\right)_{j_2>1}^{s_1^*} = \frac{\overline{s} + j_2\overline{s} - 2^j\left(j_2+1\right)\left(\overline{s}-\underline{s}\right) + \underline{s} - j_2\underline{s} + 2n\underline{s}}{2^{(j_2+1)}\left(n+1\right)\left(j_2+1\right)} \tag{2.3}$$

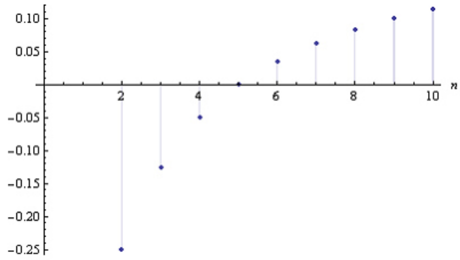
$\square$

The result of this Lemma is quite intuitive. First, as n increases (ceteris paribus), the incentive to bid up to the second stage is reduced given that the effect a shill bid produces on bidders' valuations (and drop-out prices) is lower. Second, as j_2 increases, the incentives to bid up to the second stage increases given that, for a given number of bidders, the probability of finding himself a winner in the second stage is lower. Finally, the signal distribution affects the extra gains the seller can obtain if he decides to bid more aggressively. For a given n, j_2, and $\underline{s}$, as $\overline{s}$ increases the strategy of being active at the second stage is more profitable than before given

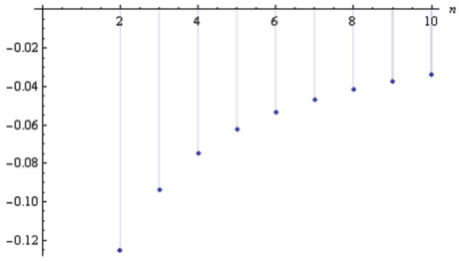
Figure 2.3: The seller's incentives in the first stage of the auction



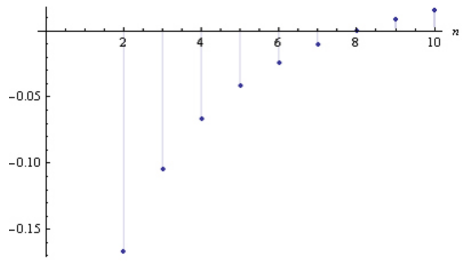
(a) $j_2 = 1$ when $s_i \in \left\{0, \frac{1}{2}, 1\right\}$



(b) $j_2 = 1$ when $s_i \in \{1, 2, 3\}$



(c) $j_2 = 2$ when $s_i \in \left\{0, \frac{1}{2}, 1\right\}$



(d) $j_2 = 2$ when $s_i \in \{1, 2, 3\}$

that the seller's effect on the price is higher and the expected price is far from his own valuation (we find the opposite effect if we fix $\overline{s}$ and we reduce $\underline{s}$).

In Figure 2.3 we can observe the incentives the seller faces in the first stage of the auction for different values of n, j_2, and for different signal distributions. In the left side we observe that it is always profitable for the seller to bid as a bidder with a medium signal ($s_2 = \frac{1}{2}$) if there is at least one remaining bidder in the first stage. As n increases, the seller' s expected gain is still positive but it is reduced given that his signal has less effect on the final price.

In the right side we observe that different values for n and j_2 not only affect the profitability of the action in the first stage but also it changes the seller's optimal strategy. Similarly to the previous example, the incentives of bidding the medium signal ($s_2 = 2$) increase as j_2 increases. However, at a given n, different values of j_2 change the seller's action at the end of the first stage. For example, when $n = 6$ the seller is better off dropping out in the first stage of the auction if $j_2 = 1$, but he is worse off if $j_2 = 2$ (in the previous example the seller is always worse off dropping out in the first stage for any value of n and j_2).

Summarizing the results of Lemma 2.3 and Lemma 2.4, we get the following result:

Proposition 2.1. *The net expected gain of doing shill bidding in an English auction, with n bidders and 3 signals, is given by*

$$
\begin{aligned}
\mathbb{E}\left(gain\right)^{P} \quad = \quad & \tfrac{1}{3^{n}}\left\{\left(\tfrac{n(3+2n)}{n+1}\right)\underline{s}+\right. \\
& \sum_{j_2=2}^{j_1}\left(\begin{array}{c} j_1 \\ j_2 \end{array}\right)\left[f\left[\tfrac{\sum_{z=1}^{2} j_z+1}{n+1}\right][1+j_1]+\sum_{j_i=2}^{j_{i-1}}\left(\begin{array}{c} j_{i-1} \\ j_i \end{array}\right)\left\{f\left[\tfrac{\sum_{j_z=1}^{3} j_z+1}{n+1}\right]\right\}\right]\Bigg\} \\
+ \quad & 2n\times\max\left[\tfrac{3\overline{s}+3n\underline{s}}{4(1+n)}-\underline{s},0\right]+\sum_{j_2=2}^{n}\max\left[2^{j_2}\left(\begin{array}{c} n \\ j_2 \end{array}\right)\times\tfrac{2^{j}(j+1)(\overline{s}-\underline{s})-\overline{s}-j\overline{s}-\underline{s}+j\underline{s}-2n\underline{s}}{2^{(j+1)}(n+1)(j+1)},0\right] \\
- \quad & \tfrac{1}{3^{n}}\left\{(1+2n)\,\underline{s}+\right. \\
& \sum_{j_2=2}^{j_1}\left(\begin{array}{c} j_1 \\ j_2 \end{array}\right)\left\{f\left[\tfrac{\sum_{z=1}^{2} j_z}{2}\right][1+j_1]+\sum_{j_3=2}^{j_2}\left(\begin{array}{c} j_2 \\ j_3 \end{array}\right)\left\{f\left[\tfrac{\sum_{j_z=1}^{3} j_z}{2}\right]\right\}\right\}\Bigg\}
\end{aligned}
$$

So $\mu = 1$ if this expression is positive, and $\mu = 0$ otherwise.

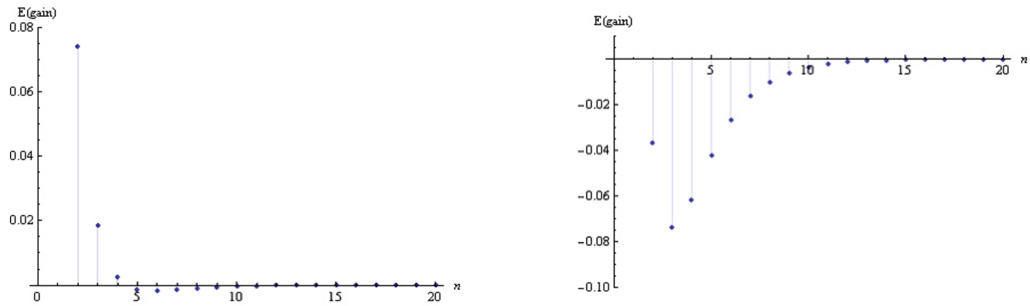
Proof. See Appendix. □

The seller's participation influences the expected gain of participation in several ways. First, the shill bid acts as a dynamic reserve price. When $\underline{s}$ is sufficiently low (closer to the seller's valuation), the seller has more incentives to enter the auction and to submit a shill bid because the price in absence of shill bidding is closer to his own valuation (as we showed in Figure 2.3). A similar effect has the decrease of $\overline{s}$ because it also reduces the expected price when he refrains from participating in the auction. In both cases, it increases the incentives to participate in the auction because finding himself the winner is less costly.

Second, the seller's participation does not only influences the final price of the object by increasing the expected second highest drop-out price, but also it influences the bidder's perception of the common value of the object. Compared to a simple auction with private values, the seller has more incentives to bid more aggressive in the auction because doing this he is sending a higher signal that moves upwards bidders' drop-out prices. However, this "perception effect" is limited. When $n = 2$ this effect does not exist because the second drop-out price is equal to the second highest valuation. This effect not only appears when $n \geq 3$, but it is maximum when n is low and it vanishes when n sufficiently high. The seller's signal has a higher effect when the number of bidders is low (but higher than two).

Third, given the nature of our model, when signals are discrete the seller always has a positive probability of finding himself a winner. As the auction goes on, the seller faces a tradeoff between increasing the price (either by increasing the second highest drop-out price itself or by increasing the price through the perception effect) and decreasing the cost given by the probability of winning the object. We can

Figure 2.4: Expected gain of shill bidding for different signal distribution



(a) For $s_i \in \left\{0, \frac{1}{2}, 1\right\}$

(b) For $s_i \in \{1, 2, 3\}$

notice that, at a given stage, the probability effect decreases as long as the number of legitimate bidders increases.

The natural question is weather the price effect is higher or lower than the probability effect, and the answer is that it depends mainly on the signals distribution. In Figure 2.4 we can observe that shill bidding is never optimal for the seller if $s_i \in \{1, 2, 3\}$, the gains of being active in the auction does not compensate the losses of finding himself the winner and it is mainly because the expected price of the object in absence of participation is sufficiently high with respect to his own valuation.

In the other hand, in the same Figure we see that participation could be profitable if the number of legitimate bidders is low and $s_i \in \left\{0, \frac{1}{2}, 1\right\}$. In this occasion, the seller has more incentives to participate in the auction when there is not a reserve price. The expected price of the object when he refrains from participating is too close to his own valuation that makes the event of winning the object not too costly.

Notice that shill bidding in not always profitable when the signal distribution is close to the seller's valuation. In our example, when the number of legitimate bidders is higher than four the seller prefers to stay out of the auction. This result resembles the effect of an optimal reserve price: in a model with interdependent values the optimal reserve price does depend on the number of bidders and it is decreasing in it. When the distribution of signals is far from the seller's own valuation, it could be the case that the seller is better off staying out of the auction for any number of bidders.

Corollary 2.1. *If the number of legitimate bidder is sufficiently high, even if they are fully myopic, the seller is always better off refraining from participating if buyers' signals are discrete.*

This result also holds for a higher number of signals in the auction, the important key is that signals should be discrete in order to not make the probability effect equal to zero. It is also valid for other bidder's value function, provided that the single crossing condition and symmetry holds.

2.6 Final Remarks

The findings in this paper could be extended in several ways. We discuss some of those extension and how the main result would change in those situations.

2.6.1 More signals

In case the number of signals increases the algebra of the model become more cumbersome but the message of this papers is not compromised: as the number of signals is higher, the probability of ties is reduced and also the intervals among bids which give the seller more flexibility in his bid. Thus, the strategy of shill bidding is more attractive from the seller's perspective.

Suppose the extreme case where the signal distribution is continuous. Izmalkov (2004) showed that the seller does not have incentive to drop out before the second highest bidder drops out. The explanation is that when there are more than two remaining bidders in the auction, the seller finds profitable to stay active in the auction because, in the one hand, if he waits a bit more he is able to send a higher signal and, in the other hand, he has no risk of finding himself the winner given that the probability that all remaining bidders drop out before him at the same price is zero.

In this case, the seller could be indifferent between entering or not in the auction but he cannot be never worse off doing shill bidding given that he can always make the probability effect equal to zero.

Example 2.2. Suppose that s_i is uniformly distributed in the interval $[1, 3]$, and $v_0 = 0$. The seller's expected gain of not participating in the auction with two legitimate bidders is equal to $5/3 \approx 1.\overline{666}$. The seller's expected gain of doing shill bidding is equal to $1201/710 \approx 1.668$. Then, the seller is slightly better entering the auction when bidders are fully myopic. However, the incentives are very low because the seller will find profitable to compete with the highest bidder only when the second highest bidder drops out at a price lower than $6/5$. If the price is higher than $6/5$, the seller does not have incentives to compete with the remaining bidder in the auction because the cost of finding himself a winner is too high compared to the gains of increasing the second price. The expected gain of getting some information rent from the winner is not so attractive compared to the current price. Also, the probability that the second signal is below $6/5$ is low and this is why, ex ante, the profitability of doing shill bidding is small (with high probability the seller drops out immediately after the second highest bidder's drop-out price changing nothing in the auction).

2.6.2 Optimal reserve price

As we mentioned before, the strategy of shill bidding can be seen as a strategy of setting an optimal dynamic reserve price. In the one hand, they present a similar effect: both are less important as the number of bidders increases. In the other hand, they are different in the way that shill bidding induces more participation than an auction with an optimal reserve price but is more "risky" when signals are discrete.

We are not extending this idea more than this comment, but it is important to notice that in this model in which signals are discrete, there could be cases where it is profitable to set an optimal reserve price but the strategy of shill bidding makes the seller worse off.

Example 2.3. Suppose a modified version of an auction with an optimal reserve price. There are two legitimate bidders that receive a private signal such that $s_i \in \{1, 2, 3\}$, both are equally probable, and $v_0 = 0$. The number of participant is known to everybody.[18] The seller sets $r = \frac{5}{3}$.[19] Then, the seller induces participation in eight out of nine possible distribution of signals and he keeps the object in the only case where both legitimate bidders receive the lowest signal. The seller's expected gain is given by $\frac{47}{27} = 1.\overline{740}$ that is strictly higher than the expected gain with no reserve price, $14/9 = 1.\overline{555}$. From the seller's perspective it would be optimal to set a reserve price although it is not optimal to shill bid (his payoff is $41/27 = 1.519$).

The profitability of setting an optimal reserve price in this example is that it increases the expected selling price at a lower cost given that the probability of ties is zero and it reduces the probability effect that a shill bidder faces when he decides to participate in the auction. Then, even when the seller shill bids optimally facing myopic bidders, he can be worse off compared to using an optimal reserve price.

[18]This assumption is not made without loss of generality. The idea of making the number of participants known in this example is to facilitate the participation of bidders who has a private signal above the reserve value and to well define their ex ante valuation conditional on them winning the object.

[19]Suppose that with indifference a bidder decides to participate in the auction or that the $r = \frac{5}{3} - \varepsilon$.

2.7 Conclusions

In private value auctions, increasing the second highest bid is the only way shill bidding could have some effect on the final price of the object. On the contrary, in common value auction, even when the seller does not find profitable to submit a bid higher than the second highest bid, his participation change bidders' perception of the common value of the object which may result in a higher selling price. One would be tempted to think that in a common value environment the strategy of shill bidding should be more profitable than in the private values case. However, we showed that, even when bidders are myopic, the seller might be better off refraining from participating.

Our contribution was extended to explain this strategy in detail, when the object is sold in an English Auction and the bidders' private information is drawn from a discrete distribution. Conditional on being in the auction, we explained how the seller update his bid based on the new information he receives as the auction goes on. We explained how the seller compares the marginal benefit and the marginal cost of remaining active up the following stage, and how this decision affects the perception of the common value of the object of legitimate bidders. This decision is affected by the actual price given the seller compares it with his own private valuation.

We showed that the incentives to shill bid depends on the signal distribution. We find out that when the number of signals is sufficiently low, even when the seller is able to increase the final expected price of the object in the auction, the cost of finding himself a winner might be sufficiently high to make the strategy of shill bidding not profitable ex-ante. Moreover, we conclude that for a discrete number of signals in the auction, if the number of participants is sufficiently high the shill bidding activity deteriorates the seller's expected profits.

Chapter 3

Physician convenience and cesarean section delivery

Chapter jointly co-authored with Shagun Khare and Alan Acosta

3.1 Introduction

The rates of cesarean section, or c-section, births vary widely across different regions. Figure 3.1 gives an idea of the disparity of rates across the world. There are stark differences between the developed and emerging world, and Latin America, for example, has rates far exceeding those recommended by the WHO. Of the ten countries with the highest c-section rates, six were in Latin America (Gibbons et al., 2010). Although there are differences across regions, there are also differences within them. Within the same country or same community, a woman's chance of getting a c-section may depend on where she lives and which hospital she goes to. Moreover, studies find that factors like race and socioeconomic status may be associated with increased or decreased probability of c-sections (Lewis, 2015). These variations point to the role of nonmedical factors in a woman's chance of getting a c-section.

Since 1985 the international healthcare community has considered the ideal target range for the rate for c-sections to be between 10% and 15% (WHO, 2015). C-section deliveries can be life-saving for both mothers and babies; but at population levels, rates higher than 15% are not associated with reductions in maternal and newborn mortality rates. Those c-sections that are avoidable are costly in monetary terms, but may also be inimical to the health of the mother and child (Burns et al., 1995). A c-section birth also limits the possibility of a natural birth for the mother in the future. Further, in the case where a woman prefers a natural delivery, an unnecessary c-section would reduce her welfare. The study of nonmedical factors that incentivize these c-sections is thus interesting from both a public health and a welfare perspective.

Among the nonmedical factors that affect c-section rates are the mother's own preferences, which may affect their demand. These preferences may be shaped by factors like personal beliefs, recovery time, differing costs and convenience. On the other hand, the physician's preferences may be shaped by differences in pay, convenience of scheduling, and time spent on each mode of delivery. As the physician has superior information over the mother, the supplier-induced demand hypothesis predicts more c-section deliveries than otherwise medically needed. Other than the mother and physician's preferences, there is also the institutional environment that plays a role. Insurance terms, hospital facilities, organization of medical teams may all affect c-section rates.

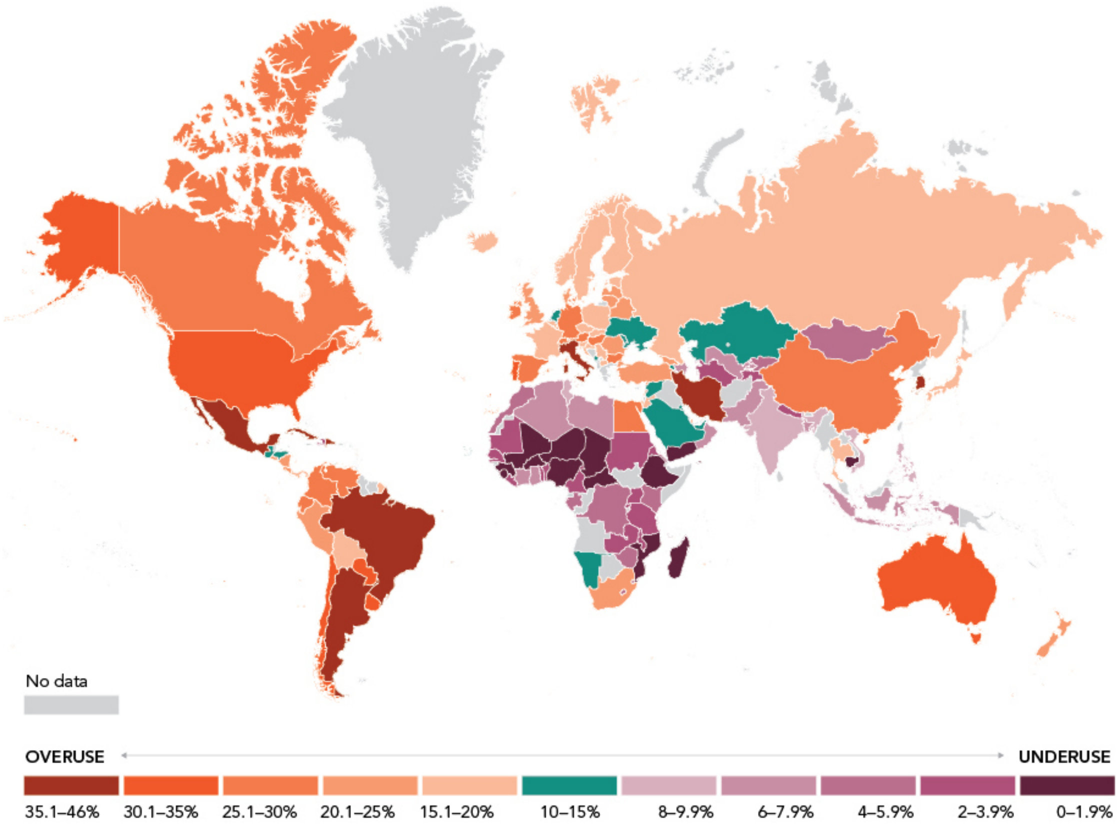
In this paper, we look at one aspect of the physician's incentives — convenience. We look at whether a woman's chance of getting a c-section depends on the period of delivery, i.e. whether it is a working day or not. Setting aside scheduled or elective c-sections, we still find that convenience matters, but only in private hospitals. In these hospitals, women who enter labour on a weekend or public holiday are 17% more likely to have an unscheduled or intrapartum c-section than those who are in labour on a weekday. There is no significant difference for women admitted to public hospitals. This difference between private and public hospitals may be attributed to the institutional environment each one provides.

We also look at the role of women's preferences in determining the mode of delivery. As the data comes from a survey of pregnant women, we have the advantage of information on their professed preferred mode of delivery. We find that preferences do play a role in delivery mode choice when it comes to scheduled c-sections. Women who state that they prefer c-sections over natural births have a higher chance of having a c-section in private hospitals, but it is not the case in public hospitals. We do not find any influence of preferences over intrapartum c-section rates.

While physicians' convenience and mothers' preferences do matter, our research finds that the institutional environment plays a defining role in defining how much these matter. In Argentina, in private hospitals the mother is assigned to a single physician who takes all decisions regarding the birth, whereas in public hospitals a team of physicians is in charge. Individual physicians' agency in public hospitals is thus limited. Changing from a private to a public hospital would reduce a woman's chance of undergoing a c-section birth on a working day and it would increase on a holiday or weekend.

The rest of the paper is organized as follows: Section 3.2 presents related literature on nonmedical factors that affect a woman's chance of having a c-section. Section 3.3 talks about the medical system in Buenos Aires, Argentina, which is the setting of our paper. Details of the survey data are given in Section 3.4. In Section 3.5 we present our identification strategy. Finally, our findings are presented in Section 3.6, and Section 3.8 summarizes.

Figure 3.1: Cesarean sections rates by country



Source: World Health Organization. Infographic: The Huffington Post (2014).

3.2 Literature review

Past research on non-medical factors influencing caesarean-section rates has looked at physicians' financial incentives (Gruber et al., 1999; Alexander, 2015; Allin et al., 2015; Green, 1978; Lo, 2008), physicians' training (Burns et al., 1995) , as well as at the use of c-sections as a defensive practice against malpractice suits (Kessler and McClellan, 1996; Tussing and Wojtowycz, 1997). A fourth explanation is that of leisure or physician's convenience, which is the focus of this study. This literature can be separated in two. One strand looks at how the hour of the day affects the probability of having a c-section, while the other looks at the impact of the day itself. Spetz et al. (2001) find evidence of increased c-sections in evening hours, but this effect is limited to cases with fee-for-service reimbursement, rather than a fixed salary. Brown (1996) looks at both time of the day as well as the day of the week. He finds that the time of the day is a good predictor for c-sections. The probability of undergoing a c-section in evening hours - especially on a Friday - is higher than other times of the day. Both Spetz et al. (2001) and Brown (1996) find this effect for elective as well as unscheduled c-sections but more recently, Lefevre (2014) [1] finds otherwise. Looking at US deliveries over 2008-2011, she finds that although there are fewer c-section deliveries in periods around long weekends, this difference can be explained by the scheduling of planned c-section births. Burns et al. (1995), looking at the effect of myriad physician level characteristics on c-section rates, find that convenience does play a role. C-section rates are higher during the daytime, and on a Friday in their data from Arizona, US. However, the authors do not distinguish between planned and unplanned c-sections.

This paper also looks at the demand side or maternal request of c-sections. While no other paper to our knowledge has looked at data on women's own professed preferences, the role of preferences has been studied more indirectly. Grytten et al. (2013) proxy immigrant mothers' preferences by the c-section rates in their countries of origin. They find a substantial role of mothers' preferences in c-section rates in Norway over 1970-2005. Furthermore, they find higher rates among those women who come from countries that stress freedom and choice and self determination. These preferences play a stronger role in scheduled rather than emergency or intrapartum c-sections. Others papers find evidence of the parents' influence in the choice of birth dates – Lo (2003) looks at increased birth rates on days considered traditionally 'auspicious' by Taiwanese, while Dickert-Conlin and Chandra (1999) and Schulkind and Shapiro (2014) find evidence of a shift of births from the first week of January to the last week of December in the United States, which they attribute to increased child tax benefits accruing to births in the previous calendar year. These papers point to the influence of mothers and more generally that of parents, in birthing decisions.

[1] She bases her result on the hypothesis that elective c-sections would then be planned for just before or just after the long holiday. If indeed the physician cared about his or her leisure, he would schedule the deliveries further away in time from the long weekend. She finds no evidence of c-sections that were displaced far enough away in time that they would indicate a physician's preference for convenience.

Considering the role of institutions in determining c-section rates, Tussing and Wojtowycz (1994) and Spetz et al. (2001) find, in the context of the US, that group-model health maintenance organizations (HMO) have lower rates of c-sections than other insurance plans. Arrieta and García Prado (2016) find a role of capacity constraints in delivery mode choice in the public sector in Peru. C-sections may be used as a means to free up beds during high demand periods.

3.3 Background

In Argentina, hospitals are not required to report c-section rates; and there is no official estimate for neither public nor private hospitals. Unofficial statistics determine the rate to be 35%-40% on average, with a much higher rate in private hospitals (about 50%) than public ones (about 25-30%).[2] With the aim to understand the disparity in the rate of c-sections in public and in private hospitals, it is important to understand the differences in their structure and in the health care they provide.

3.3.1 Health system in Argentina

The Argentinian health system has two types of hospitals - public ones that are free for everyone, and private hospitals that charge for services. In practice, private hospitals are exclusively accessed by those with either private health insurance or social security cover, both regulated by the Superintendency of Health (SSS), an independent legal entity which reports to the Ministry of Health.[3] The part of the population that do not have a formal job and cannot afford to pay a private insurance, receive medical attention in public hospitals.[4] Public hospitals are financed by the Ministry of Health and by the money collected from use of services in the private and in the social security sectors.

3.3.2 Maternity health care

Maternity health care presents many differences in public and private hospitals, mostly due to their organization before, during and after the baby is born.

[2] Sources: IOMA (2015), IECS

[3] The social security sector in Argentina caters to those employed in the formal sector. All employers and employees in the formal sector are required to make payments to a trust fund towards this. It covers all workers and their families, as well as those retired. It acts principally as a paying agent, purchasing health services from the private sector

[4] A special case is the fund for retired people, the Programa de Atención Médico Integral (PAMI). It contracts out mainly to private providers, although the demand for health services is also partly directed at the public sector.

In public hospitals, there is not a particular physician or midwife that is in charge of following the prenatal care of a particular woman. On the contrary, all workers in the maternity department work in teams which means that, in a given shift, a woman can receive the medical attention of any of the workers in that shift. During pregnancy, it means that a women might or might not receive the medical attention of the same physician/midwife, and she cannot choose who is the person in charge of the follow up examinations. Something similar happen when the birth day arrives and the woman is admitted into the hospital. During labor, the woman receives care of the group of physicians and midwives that are working at the time she arrives. However, if the woman is still in labor when a new shift arrives, the newcomers continue with her care. Decisions about how to proceed in every case are taken by the group, and neither physicians nor midwives have any particular interest in being present at the moment a woman delivers the baby given that they are paid a flat fee that only depends on the hours they work in their shift.

Private hospitals are organized differently. Women choose a particular physician or midwife during the prenatal care and these are the ones who take care of the women not only during the follow up examinations, but also during the delivery. Women develop a very close relationship with their physicians and midwives, and they demand to them a personalized care. The advantages of this type of relationship is that women feel more confident during their pregnancies given that, at the moment of delivery, they knew the person in charge in advance. This is good either for women but also for private physicians that can better estimate their workload in the upcoming months. However, it also raises disadvantages for both: women become too dependent to their private physician/midwife, and physicians might have periods of unexpected hard workload being very difficult to organize themselves. Also, it is more risky for physicians for two reasons: first, because they are paid for delivery which makes them also more dependent to women, and second, because they are the main (if not the only) responsible for the outcome.[5] .

3.4 Data

The data needed to conduct this analysis was facilitated by the Mother and Child's Health Research Department, Institute for Clinical Effectiveness and Health Policy (IECS) that conducted a prospective cohort study on women's preferences for the mode of delivery. The data set comes from survey data and medical records from

[5]Obstetrics is one of the specialities that faces more malpractice claims, and it accounts for the most payments. Also, physicians in obstetrics and gynecology are projected to face a claim by the age of 45 years (Jena et al. (2011)).

382 pregnant women from September 2010 and December 2011. Enrolled women were surveyed to obtain their socioeconomic characteristics and their preference for mode of delivery during the third trimester, particularly if they preferred to give birth by c-section or vaginal delivery. Women were followed-up until delivery when their actual mode of delivery was assessed and the data from their medical records were collected, including the day but not the hour of delivery.

The selection criteria included first-time mothers-to-be (nulliparous women), aged 18 to 35 years, expecting just one child (singleton pregnancies) and a live fetus over 32 weeks of gestational age. The sample is restricted to women between the ages of 18 and 36 years old, in order to maintain a similar age distribution between the private and public hospitals and to reduce the potential confounding due to differences in the age of participants across hospital types. In addition, women with fertility assisted pregnancies, known pre-existing major diseases, with pregnancy complications, or with a medical indication of elective CS, were excluded from the sample.

The data was collected in three public hospitals and three private hospitals in and around the City of Buenos Aires, which typically see more than 2000 deliveries per year (Mazzoni et al., 2016). The hospitals were chosen based on a convenience sample of locations where other research studies have been conducted by IECS. Out of the 382 women surveyed, 182 were admitted to private hospitals and 198 to public ones.[6][7]

The data collected about deliveries is quite detailed. In particular, about c-section, we know if it was scheduled or not. This gives us a sizeable advantage with respect to other papers that try to identify the effect of convenience on the mode of delivery given that we expect all scheduled c-sections to be perform on convenient days. From the data we can identify two types of c-sections, intrapartum c-sections (ICS) and elective (or scheduled) c-sections (ECS), and if labor was induced or not. An elective c-section is the one that is scheduled by the doctor to take place before labour begins.[8] Also, an elective c-section can also be on maternal request and it is a decision of the physician and the hospital to listen or not the woman's desire. Far more frequently, the need for a CS isn't obvious until a woman is well into labor.

[6]Two women were removed from the dataset: one because she was untrackable during the follow up and another one because she had a multiple pregnancy.

[7]In Argentina, 99% of deliveries occur at either public or private hospitals. The sample is compatible with the national data from 2010 that says that 55% of the women delivered in public hospitals, and 44% in private ones (Ministerio de Salud de la Nación. Dirección de Estadísticas e Información de Salud., 2010).

[8]There are multiple reason why the physician may peg a woman for the procedure in advance of her due date such us certain medical conditions, infections, the baby's health, placenta problems, etc.

An intrapartum c-section is the one that happens once labour has begun, and there are also many reasons for it, such us when labor is stalled, exhaustion or fetal distress, etc. In many countries, intrapartum c-section are also called "emergency CS". However, in Argentina the denomination is a bit different and emergency c-section could happen during labor or not and, if it is the case, it is indicated in our data.[9]

3.4.1 Summary statistics

Table 3.1: Type of deliveries by hospital

	Public	Private	Total
All births	197	182	379
Natural births	129	102	231
as % of all births	65,48%	56,04%	60,95%
C-sections	68	80	148
as % of all births	34,52%	43,96%	39,05%
Elective c-sections	9	27	36
as % of all women	4,57%	14,84%	9,50%
Intrapartum c-sections	57	53	110
as % of women in labour	30,32%	34,19%	32,07%

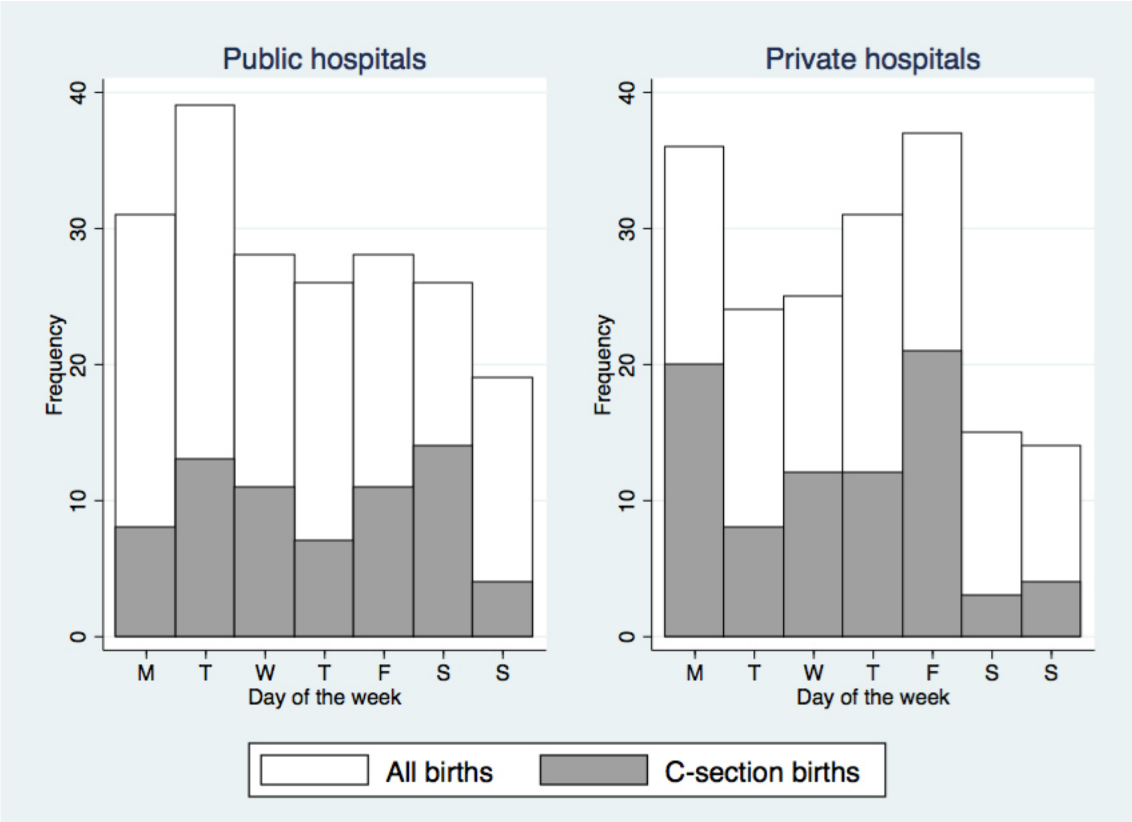
Table 3.1 summarizes the data on types of delivery modes. In our sample, 34.5% of births in public hospitals and 44% of births in private hospitals were by c-section. The disparity in c-section rates between public and private hospitals is thus about 10%, but this differential is lower than the unofficial estimate for Argentina (see Section 3.3). Looking further into scheduled and unscheduled c-sections, we see that the larger contributor to this difference is the elective c-section rate. Ten percent of all women in our sample have an elective c-section, but women in private hospitals have them three times more often than those in public hospitals. The rate of intrapartum c-sections – c-sections decided once the woman enters labour – is also higher in private hospitals, but the difference is not as stark. Table C.2 in the appendix gives us birth data broken down by hospital.

How are the births spread across time? Figure 3.2 shows the distribution of births by the day of the week. Here we can notice some interesting trends: private hospitals

[9] For example, if the reason for a c-section is *"oligohydramnios and altered doppler"*, this is an elective c-section. However, if the doppler is high altered, the elective c-section should be performed as soon as possible, and this could be considered as an emergency c-section. A case of *"eclampsia"* could end up in an emergency c-section either when the woman is in labour or not. In this case, the emergency c-section could be consider intrapartum c-section or not. Finally, a case of *"placental abruption"* in an emergency, but could also happen during labor or not.

have a peak of deliveries - mainly c-section deliveries - on Mondays and Fridays. The weekends seem to be relatively calm, with a drop in c-section deliveries. Public hospitals have a peak on Tuesday, though this peak does not seem be attributed to c-sections. In the Appendix, Figure C.1 and Figure C.2 present the same graphics for elective and intrapartum c-sections, respectively.

Figure 3.2: Births by the days of the week



When considering convenience of the physician or their leisure demand, we are not only interested in weekends and weekdays, but also in holidays over the year. Table 3.2 gives us an idea of how births are spread by working and nonworking days.[10] Here we see that although two-thirds of the days under consideration were working days, three-fourths of babies were delivered on these days. In private hospitals in particular, on average, almost double the number of babies were born on a working day as compared to a nonworking day.

[10]Our deliveries range from 25 Sep 2010 (Saturday) to 27 Dec 2011 (Tuesday). We begin and and our calendar with these dates. There are 459 days between these two dates (including both dates). Of these, we have 66 weekends (132 days). Of weekend days, 6 days were also public holidays. In addition, 19 public holidays fell on weekdays. Considering public holidays and weekends as inconvenient days where the doctor's demand for leisure is high, we have $132+19 = 151$ inconvenient days, and $459 - 151 = 308$ convenient days.

Table 3.2: Births by type of day

	Working day	Weekend + public holiday	Total
Total calendar days	308	151	459
	67.10%	32.90%	100.00%
All hospitals			
Births	289	90	379
	76.25%	23.75%	100.00%
Avg. births per day	0.938	0.596	0.826
Public hospitals			
Births	141	56	197
	71.57%	28.43%	100.00%
Avg. births per day	0.458	0.371	0.429
Private hospitals			
Births	148	34	182
	81.32%	18.68%	100.00%
Avg. births per day	0.481	0.225	0.397

We reports the sociodemographic characteristic of women recruited from public and private hospitals in Table 3.3. It also reports women preferences for the type of delivery declared during the survey and the actual type of delivery they had.

Women became mothers for the first time at around 26 years old. However, it changes dramatically between hospitals: while in public hospitals women became mothers at almost 23 years old, in private hospitals they do it seven years later (29.9 years old).[11]

In terms of education, more than 90% of women have at least high school education, either complete or incomplete. Nevertheless, the asymmetry between public and private hospitals remains. The majority of women from public hospitals has high school education (71%), but in private hospitals the level of education is higher, where 82% of women have tertiary or university level.

Almost each woman in private hospitals is married or in couple (93.4%), in opposition to public hospitals it is less likely women to be in a stable relationship (69.9%). In addition, women in private hospitals women are more likely to be employed and to be covered by health insurance.

[11] This is compatible with the information at national level in 2006 that says the average age of new mothers was 28.1 years. However, this average varies by socioeconomic and educational level of women: 27.2 years old for women who finished college, 23.3 years old for women who completed secondary education, and 21.3 years old for women who completed primary education (Lupica and Cogliandro, 2010).

Table 3.3: Women's characteristics

All hospitals	N	mean	sd	min	max
Age	379	26,214	5,375	18	36
Education					
Elementary School	378	0.093	0.290	0	1
High School	378	0.458	0.499	0	1
Tertiary/University	378	0.450	0.498	0	1
Married/in couple, or not	378	0.812	0.391	0	1
Working or not	375	0.477	0.500	0	1
Insured or not	379	0.464	0.499	0	1
Prefers CS	367	0.074	0.261	0	1
Had CS	379	0.391	0.489	0	1
Public hospitals					
Age	197	22,792	4,104	18	35
Education					
Elementary School	196	0.179	0.384	0	1
High School	196	0.714	0.453	0	1
Tertiary/University	196	0.107	0.310	0	1
Married/in couple, or not	196	0.699	0.460	0	1
Working or not	197	0.157	0.365	0	1
Insured or not	197	0.000	0.000	0	0
Prefers CS	197	0.081	0.274	0	1
Had CS	197	0.345	0.477	0	1
Private hospitals					
Age	182	29,918	3,946	18	36
Education					
Elementary School	182	0.000	0.000	0	0
High School	182	0.181	0.386	0	1
Tertiary/University	182	0.819	0.386	0	1
Married/in couple, or not	182	0.934	0.249	0	1
Working or not	178	0.831	0.375	0	1
Insured or not	182	0.967	0.179	0	1
Prefers CS	170	0.065	0.247	0	1
Had CS	182	0.440	0.498	0	1

In addition, within the same group of women, it is more likely an older woman in her twenties to be more educated, to be employed, and to be in a stable relationship. Also, considering women of different groups (public vs. private), differences are bigger. As we mentioned above, public health in Argentina is perceived of being of lower quality than the private one, which results in women of high socioeconomic status to choose to pay for private health. In addition to this, more educated women are more likely to be employed and to receive social security that, in most of the cases, partially cover private health care.

Table 3.4: Preference for mode of delivery and its rate of CS

	Preference for VD	Rate of CS
Public hospital	91.88%	33.70%
Private hospital	93.53%	40.25%
Total	*92.64%*	*36.76%*
	Preference for CS	Rate of CS
Public hospital	8.12%	43.75%
Private hospital	6.47%	72.73%
Total	*7.36%*	*55.56%*
	No preference	Rate of CS
Public hospital	0%	0%
Private hospital	6.59%	66.67%
Total	*6.59%*	*66.67%*

Table 3.4 presents us information on women's professed preferences. Despite the different characteristics between the two groups of women, we see that there is no significant difference between women's preferences for mode of delivery. Only 8.1% of women in the public sector and 6.5% of women in the private sector expressed a preference towards cesarean section ($p = 0.55$). A minority showed indifference about the mode of delivery in the private sector (6.6%), but none of women in the public sector did. The rate of c-section is higher among the group of women who declare having a preference towards c-section rather than vaginal delivery, in both public and private hospitals (44% in comparison with 34%, and 73% as opposed to 40%, respectively). This numbers would suggest that women's preferences are taken into account when deciding the mode of delivery.

Moreover, among the group of women who are indifferent about the mode of delivery in the private sector, the rate of c-section is closer to the group of women who prefer a c-section, suggesting that indifference could play a role of increasing the rate of c-section in the private sector.

3.5 Identification strategy

We want to identify the effect of physician's convenience and mother's preferences over the rate of c-sections in public and private hospitals. Given the differences in how these hospitals are organised, we expect these factors to matter more for private hospitals. This is because in private hospitals, each doctor individually handles a birth. This means that they are affected by the timing and duration of delivery, but also that they can take all decisions regarding the delivery. In public hospitals, on the other hand, a team of doctors handles each case. No one doctor has complete say over medical decisions, nor is the burden of delivery only on one doctor.

In studying c-sections, we first make a distinction between those that are scheduled ahead of time (elective c-sections), and those that are initiated only once the woman goes into labour (intrapartum c-sections). We make this distinction because the extent and manner that nonmedical factors may affect their likelihood are different. We expect that preferences should matter for elective c-sections, but not for intrapartum ones. Further, since elective c-sections are planned ahead in time, the date of delivery is more of an outcome of this decision. However, the date of delivery could be a potential predictor of intrapartum c-section rates.

Looking at elective c-sections, we consider whether the hospital (i.e. whether it is private or public) and whether the woman herself prefers a c-section over a natural birth matters. For this we run a probit regression, controlling for women's age as well as hospital level characteristics.[12] For the latter variable, we include hospital level fixed effects. This is done to control for possible omitted variables that could affect c-section rates such as number of beds or number of doctors.

When it comes to intrapartum c-sections, we exclude from our sample those women who undergo an elective c-section. Doing so, we consider only those that enter labour. Among these, some go on to have intrapartum c-sections and others, natural births. Our main question is how a woman's chance of getting a c-section once in labour is affected by the hospital, and the day that she has gone into labour. Our hypothesis is that doctors would like to avoid work on an inconvenient day, and would want to shift births to days before/after these days – to convenient days. We follow the same regression as for elective c-sections, but also include convenience considerations.

To include physician convenience, we consider different specifications of "convenient days". To understand these, it is easier to understand what we consider

[12]We could control for other socio-economic characteristics of the woman, however age was the only medically important one. Insurance could be important but perfect bifurcation. Trying to be judicial with our use of controls given sample size.

as inconvenient days. Convenient days are the complement set of the inconvenient days, i.e. any day that is not an inconvenient day is a convenient day. In the first specification, inconvenient days are simply the weekend and public holidays. The second specification includes these, and also the day before holidays.[13] Since c-sections require follow up care, a doctor may wish to avoid c-sections just before a day off. The third specification is similar to the second one but excludes the previous days before holidays falling midweek (e.g. a holiday on a Wednesday doesnot render Tuesday as inconvenient). In this specification, inconvenient days are weekends, holidays and days that are part of 'long weekends'. Table C.1 describes the different specifications visually.

If physicians want to shift deliveries off inconvenient days, then we should expect more c-sections on convenient days. However, there are two different effects that affect the overall rate of c-sections on convenient days. First, there is the effect of elective c-sections. When a delivery is planned in advanced, then physicians choose to schedule it on a convenient day.[14] Second, the effect of intrapartum c-sections: physicians might not want to wait for the normal process of labour and they might decide to proceed with a c-section, even when it was not strictly necessary. The first effect is an affect that we expect either in public and in private hospitals. Nevertheless, the second one is an effect that, in case it exists, it should be observable in private hospitals, where physicians are more interested in speeding up the process.

Our data does not allow us to control for doctor's characteristics. We do not know how training or years of experience etc. could determine delivery mode. However, we can safely exclude physicians financial incentives as a factor. This is because, as mentioned in Section 3.3, doctors in Argentina are paid for delivery and not for the type of procedure.

We assume different definitions of convenient days. However, all of them have in common that in weeks when there is no public holiday, the convenient period is from Monday to Friday. Physicians may want to avoid working on weekends, so we might observe more c-sections performed during the convenient period.

In weeks where there is a public holiday, several specifications are taken into account depending on the day of the week that this public holiday falls. We do not expect the same effect if a public holiday is observed on a Monday, than if it is observe in mid-week. The reason is quite simple, a holiday on a Monday creates a three-day weekend, also called "long weekend", and it induces workers, for instance,

[13] If a public holiday is a Monday, given the effect of the long weekend, the previous day is defined on Friday, but if the holiday falls on a Saturday or a Sunday, the previous day is not considered as an inconvenient day in this specification. See Table C.1 for more details.

[14] Hospitals are better prepared in case of an emergency, etc.

to use them to plan city trips with their families. Physicians are not exempt of it. However, we test different hypothesis and we show that results are robust to different specifications (see Table C.1 for more details).

In a first specification, convenient days are defined as any day of the week except Saturday, Sunday and public holidays (conv. day (1)). Our second specification also considers as a non-convenient day the previous day before holidays, whatever it is on Monday or in mid-week. If physicians don't want to put in risk their leisure time, they would rather avoid intrapartum c-sections the days before public holidays also, given that performing an intrapartum c-section means that a private physician has to come back the following day to the hospital to check up the woman and the baby. If a public holiday is a Monday, given the effect of the long weekend, the previous day is defined on Friday, and if it is on Saturday or Sunday, the previous day is not considered (conv. day (2)). Our third specification, considers days before public holidays only when a public holiday is on Monday and a delivery might threaten physicians' leisure time in a long weekend. This specification is similar to our second one, but the difference is that a public holiday in mid-week does not make inconvenient the previous day (conv. day (3)).

To assess the effect of physicians' convenience on the cesarean decision, we initially run probit regressions of the form

$$CS_i = f(\alpha + \beta_1 PrH_i + \beta_2 conv_i + \beta_3 PrH_i \times conv_i + \beta_4 pref\_ces_i + \beta_5 PrH_i \times pref\_ces_i + \beta_6 age_i + \varepsilon_i) \quad (3.1)$$

where

CS_i	is equal to one if individual i received a c-section, and zero otherwise
PrH_i	is an indicator if individual i delivers in a private hospital
$conv_i$	is an indicator if individual i delivers on convenient day
$pref\_ces_i$	is one if the stated preference of individual i is a c-section
age_i	is the age of individual i at the moment of delivery

We are interested in seeing that given two women with the same $pref\_ces_i$, how the other variables on the RHS affect the outcome CS_i. In this regression, the c-section decision is modelled as a function of the mother's age and preferences, as well as the type of hospital and the type of day of delivery. However, as documented above, the date of delivery is an outcome and not a determinant of elective c-sections and this regression does not illustrate a causal relationship in this case. Our preferred specification is

$$ECS_i = f\left(\alpha + \beta_1 PrH_i + \beta_4 pref\_ces_i + \beta_5 PrH_i \times pref\_ces_i + \beta_6 age_i + \varepsilon_i\right) \quad (3.2)$$

where ECS_i is equal to one if individual i scheduled a c-section, and zero otherwise;[15] and

$$ICS_i = f(\alpha + \beta_1 PrH_i + \beta_2 conv_i + \beta_3 PrH_i \times conv_i + \beta_4 pref\_ces_i + \beta_5 PrH_i \times pref\_ces_i + \beta_6 age_i + \varepsilon_i) \quad (3.3)$$

where $IECS_i$ is equal to one if individual i received a c-section, and zero otherwise. As we already mentioned, the specification for elective c-sections takes into account the whole sample (given that this decision is taken over the whole sample). Nevertheless, when using the second specification, we take into account only women that enter labour.

3.6 Results

The results for all c-sections - elective and intrapartum - are given in Table 3.5. While we can see the hospital (private or public) matters for c-section rates, the day of delivery only seems to matters in private hospitals.[16] Once we include hospital fixed effects, it is not possible to rely on the coefficient of the variable "Private hospital" anymore. However, we can still trust in the interactions, and convenience remains significant for private hospitals. These results, however, do not tell us what determines the rate of c-sections. This is because the day of delivery (variable convenient day or 'Conv. day') could be either a determinant or an outcome of our regressand – depending on whether it is an elective or intrapartum c-section. The next two subsections look at each of these separately, to be able to actually explain the rates that we observe.

3.6.1 Elective c-sections

An elective c-section is a c-section delivery that has scheduled by the doctor ahead of time. These are usually done because the mother or the fetus are at risk from a

[15] In this specification we do not know if the c-section was scheduled by the doctor for a medical condition or not. However, given the information on women's preferences we can control for the women's will.

[16] The effect of age is positive and significant when we remove the variable "Age sq.".

vaginal delivery, such as in the case if the baby is in breech position or if the mother has previously had a c-section delivery. Nevertheless, the elective c-section can also be scheduled for the woman's demand.

Table 3.6 presents the results of the probit estimation of elective c-sections. As the day of the delivery is now an outcome of the decision to have a c-section, we have omitted it from our dependent variables. Specification (2) controls for hospital level fixed effects.[17]

Table 3.7 gives us the predicted probability of an elective c-section birth for women going to each hospital. Women in private hospitals have a 2.7 times higher probability of planned c-section births than women in public hospitals. However, part of this difference could be explained by the difference of age in the two groups of women itself. To correct for this, Table 3.8 gives us the probability of an elective c-section for the average aged woman (26 years old) in each hospital. We see that the difference is a little narrower: the probability a 26 year old woman undergoes an elective c-section in a private hospital is double that in a public hospital. Figure 3.3 gives us these probabilities over all the ages of women in the sample. We see that the probability of having an elective c-section increases unambiguously with age, but remains consistently higher in private hospitals.

[17] In this specification, the observations (338) are fewer than in the first specification as in one of the hospitals, there were no reported elective c-sections (hospid=6, public hospital).

Table 3.5: C-section: C-section: probit estimation

VARIABLES	(1) ces	(2) ces	(3) ces	(4) ces	(5) ces	(6) ces
Private hospital (PrH)	-0.580*	-0.606**	-0.652**	-	-	-
	(0.317)	(0.290)	(0.301)	(0.436)	(0.421)	(0.427)
Conv. day	-0.0882	-0.108	-0.0866	-0.139	-0.151	-0.123
	(0.204)	(0.196)	(0.202)	(0.208)	(0.199)	(0.202)
PrH x Conv. day	0.651*	0.729**	0.762**	0.750**	0.786**	0.831**
	(0.334)	(0.311)	(0.318)	(0.342)	(0.315)	(0.324)
Prefers CS	0.279	0.278	0.281	0.291	0.289	0.294
	(0.328)	(0.329)	(0.328)	(0.335)	(0.336)	(0.335)
PrH x Prefers CS	0.464	0.428	0.423	0.491	0.449	0.446
	(0.541)	(0.542)	(0.543)	(0.552)	(0.552)	(0.553)
Age + 18	0.0327	0.0321	0.0306	0.0277	0.0263	0.0254
	(0.0515)	(0.0516)	(0.0516)	(0.0522)	(0.0523)	(0.0523)
Age sq.	5.28e-05	0.000108	0.000265	-4.64e-05	6.20e-05	0.000188
	(0.00285)	(0.00285)	(0.00286)	(0.00289)	(0.00289)	(0.00289)
Constant	-0.522**	-0.513**	-0.524***	-1.073***	-1.063***	-1.078***
	(0.233)	(0.224)	(0.225)	(0.355)	(0.354)	(0.353)
Observations	367	367	367	364	364	364
Hospital FE	NO	NO	NO	YES	YES	YES
Convenience definition	(1)	(2)	(3)	(1)	(2)	(3)

Notes: columns (1), (2) and (3) use different specifications of convenient days defined in the previous Section. Columns (4), (5) and (6) use the same specification for (1), (2) and (3) but adding fixed effects, respectively.

Standard errors in parentheses

$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

To consider the role of women's professed preferences of delivery mode, we turn to Table 3.9. Here for each group of women (sorted along the dimension of preferences and hospital), we have the expected probability of a c-section. The starkest difference is for women who prefer c-sections over natural births, and who are admitted to private hospitals. Their chance of having a scheduled c-section is five times that of any other class of women. Preferences don't seem to make much of a difference in public hospitals. Figure 3.4 presents the same information but at each given age. We see that the probability of having a planned c-section increases with age across the board, and that women in private hospitals who prefer c-sections are much more likely to have them. These women seem to explain most of the difference of elective c-section rates between public and private hospitals.

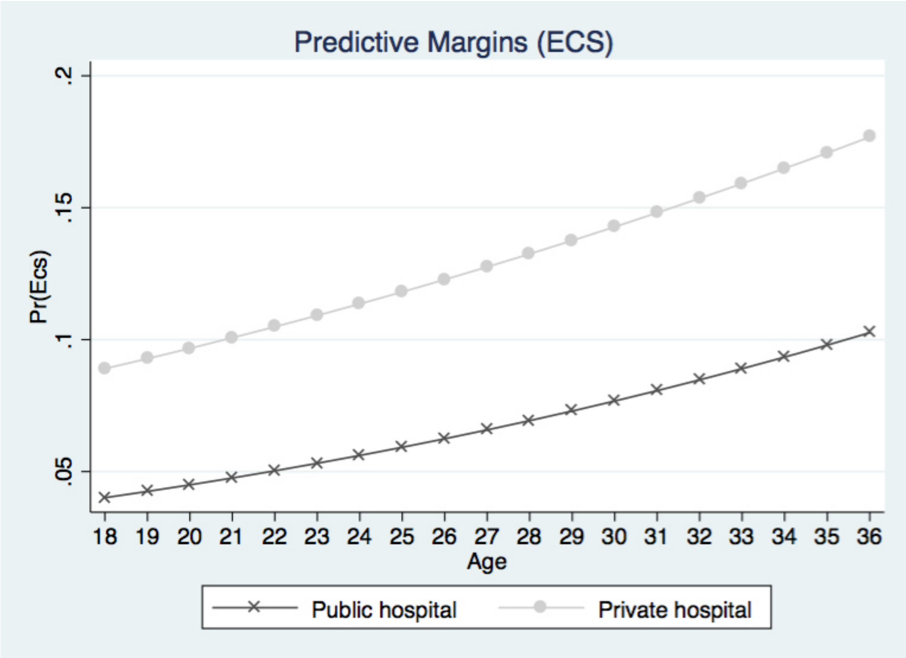
To summarize, women in private hospitals are much more likely to have an elective c-section, especially if they themselves would prefer to have one. These women then give birth during the week (on a convenient day), mostly on a Friday, as we can see from Figure C.1 in the Appendix. Those women who have an elective c-section in public hospitals too give birth on weekdays, but the most likely day of birth is a Tuesday and not a Friday.

Table 3.6: Elective c-section: probit estimation

VARIABLES	(1)	(2)
Private hospital (PrH)	0.339	-
	(0.289)	(0.389)
Age	-0.109	-0.1085
	(0.077)	(0.083)
Age sq.	0.008*	0.007*
	(0.004)	(0.004)
Prefers CS	0.106	0.0412
	(0.532)	(0.578)
PrH x prefers CS	1.087	1.388*
	(0.670)	(0.741)
Constant	-1.492^{***}	-1.813^{***}
	(0.270)	(0.389)
Observations	367	338
Hospital FE	NO	YES

Standard errors in parentheses
$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Figure 3.3: Predicted probability of undergoing an elective c-section



Note: this is using the specification without FE, without age sq. Similar if both used.

Figure 3.4: Predicted probability of undergoing an elective c-section

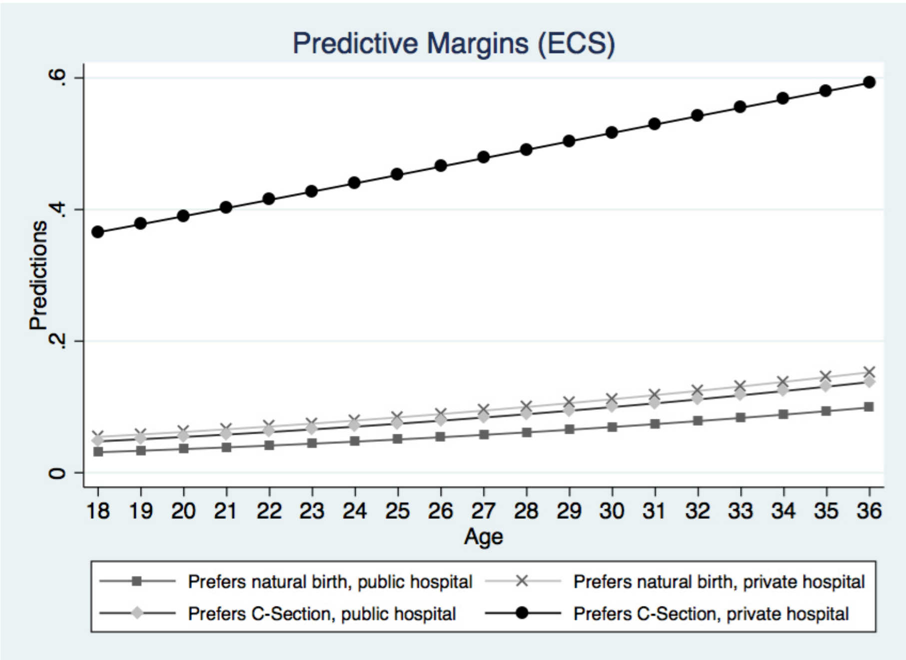


Table 3.7: Elective c-section: marginal effects for each hospital

VARIABLES	(1)	(2)
Public hospital	0.0467***	-
	(0.0150)	(0.0170)
Private hospital	0.140***	0.145***
	(0.0253)	(0.0250)
Observations	367	338
Hospital FE	NO	YES

Standard errors in parentheses
$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Table 3.8: Elective c-section: marginal effects for a 26 y.o. in each hospital

VARIABLES	(1)	(2)
Public hospital	0.056***	-
	(0.0191)	(0.0211)
Private hospital	0.113***	0.123***
	(0.0301)	(0.0309)
Observations	367	338
Hospital FE	NO	YES

Standard errors in parentheses
$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Table 3.9: Elective c-section: marginal effects

VARIABLES	(1)	(2)
Prefers natural birth, public hospital	0.0436***	-
	(0.0151)	(0.0170)
Prefers natural birth, private hospital	0.111***	0.0847***
	(0.0251)	(0.0251)
Prefers c-section, public hospital	0.0650	0.0576
	(0.0615)	(0.0619)
Prefers c-section, private hospital	0.515***	0.553***
	(0.153)	(0.170)
Observations	367	338
Hospital FE	NO	YES

Standard errors in parentheses
$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

3.6.2 Intrapartum c-sections

As we previously mentioned, an intrapartum c-section is a procedure that takes place once the woman is on labour. During a first-time birth, a first labor lasts 16 hours on average, however, this can vary tremendously.[18] If a woman arrives in the hospital once in labour, we assume that no elective c-section was previously scheduled and so there is no clear indicator that the woman or baby were at risk.[19] Then, this woman might deliver her baby either vaginally or by intrapartum c-section. Figure C.2 in the Appendix shows us the distribution of delivery modes once in labour for our sample. Overall, of the women who enter labour, 30.3% go on to have an intrapartum c-section in public hospitals in our sample, while 34.2% have one in private hospitals (Table C.3 in the Appendix). So both elective and intrapartum c-section rates are higher in private hospitals, though the difference for intrapartum c-sections is not much (the difference is not statistically significant, $p = 0.05$).

There are many thing we want to test in the model for intrapartum c-sections. First, we want to know if the professed preferences for delivery mode is taken into account when women are in labour. Since preferences do not play a role in public hospitals for elective c-sections, we expect this to be maintained for intrapartum ones. Further, we expect preferences to matter less for intrapartum c-sections than for elective c-sections, where the doctor is better disposed to account for nonmedical factors. Second, we want to know if the rate of intrapartum c-sections is higher for private hospitals. If the scheduling effect is real for private hospitals, we should observe a higher rate of intrapartum c-sections only due to the fact that a woman is delivering in a private hospital. But, most importantly, we should observe a higher rate of intrapartum c-sections on convenient days: if physicians in private hospitals can have an effect in the timing of delivery, then we should observe more intrapartum c-sections before and after inconvenient days. Last, but not least, we want to know the effect of age on intrapartum c-sections. Age is often cited as a reason for the rise of c-sections. However, this may be the confounding effect of health issues such as high blood pressure, diabetes or heart disease, which increase with age. In our sample, the women have none of these prexisting conditions and so we can truly isolate the effect of age on the probability of having a c-section.

Table 3.11 presents our probit estimates for the three specification of convenient days. Results are robust to the different specifications. About the preference for

[18] Even when the early stage of labour can last for two or three days, most of women may not even notice that they are in early labour. Then, most of women are admitted into a hospital when labour is at more advanced levels and delivery is imminent (within 24 hours).

[19] It may be the case that the woman goes into labour before the schedule elective c-section, but we assume this is not the case.

mode of delivery, it seems that it does not change the probability of having an intrapartum c-section. As we previously mentioned, if this preference is taken into account, it is more likely to be significant in elective c-sections.

Older women have a higher probability of having an intrapartum c-section, but its coefficient is not significant. The average predicted probability of undergoing an intrapartum c-section is 33%, but it is 8% lower for an eighteen-year-old woman and reaches 8% higher at 35 years old.[20] This result suggests that increasing maternal age is linked with a higher risk of emergency delivery, in a low-risk, first time mother cohort.[21]

From Table 3.11 we can also see that delivering in a private hospital on inconvenient days has a negative effect on the probability of having an intrapartum c-section. But most interesting is the result that comes from the coefficient of convenient day and its interaction with private hospital: while being in labour in a convenient day does not change the probability of having an intrapartum c-section in a public hospital (in comparison with inconvenient days), it does increase the probability in a private hospital, in all specifications. Then, what we observe is that even when the overall rate of intrapartum c-section is similar in public and private hospitals, its distribution in convenient and inconvenient days is quite different: physicians in private hospitals shift deliveries off leisure periods, performing more intrapartum c-sections on convenient days.

Table 3.10: Average discrete effects from the Probit model

Public hospital	
Conv. day	0.284***
Inconv. day	0.342***
Difference	-0.058
Private hospital	
Conv. day	0.380***
Inconv. day	0.212***
Difference	0.168**
All hospitals	
Conv. day	0.325***
Inconv. day	0.286***
Difference	0.04

Standard errors in parentheses
$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

[20]The average discrete effect of age is similar in both, private and public hospitals.
[21]Similar results were found in Herstad et al. (2015).

Table 3.11: ICS: Probit estimation

VARIABLES	(1) ics	(2) ics	(3) ics	(4) ics	(5) ics	(6) ics	(7) ics
Private hospital (PrH)	-	-0.613*	-0.597**	-0.639**	-	-	-
	(0.365)	(0.321)	(0.294)	(0.306)	(0.443)	(0.428)	(0.434)
Conv. day		-0.199	-0.197	-0.158	-0.245	-0.252	-0.186
		(0.208)	(0.201)	(0.204)	(0.213)	(0.206)	(0.209)
PrH x conv. day		0.696**	0.721**	0.743**	0.751**	0.780**	0.777**
		(0.342)	(0.319)	(0.327)	(0.350)	(0.324)	(0.333)
Age	0.055	0.0597	0.0582	0.0570	0.0539	0.0518	0.0508
	(0.559)	(0.0553)	(0.0553)	(0.0553)	(0.0562)	(0.0562)	(0.0562)
Age sq.	-0.002	-0.00197	-0.00186	-0.00170	-0.00194	-0.00180	-0.00164
	(0.003)	(0.00310)	(0.00310)	(0.00311)	(0.00314)	(0.00314)	(0.00315)
Constant	-1.190***	-0.593**	-0.601***	-0.623***	-1.053***	-1.044***	-1.079***
	(0.336)	(0.236)	(0.229)	(0.231)	(0.358)	(0.358)	(0.357)
Observations	340	343	343	343	340	340	340
Hospital FE	YES	NO	NO	NO	YES	YES	YES

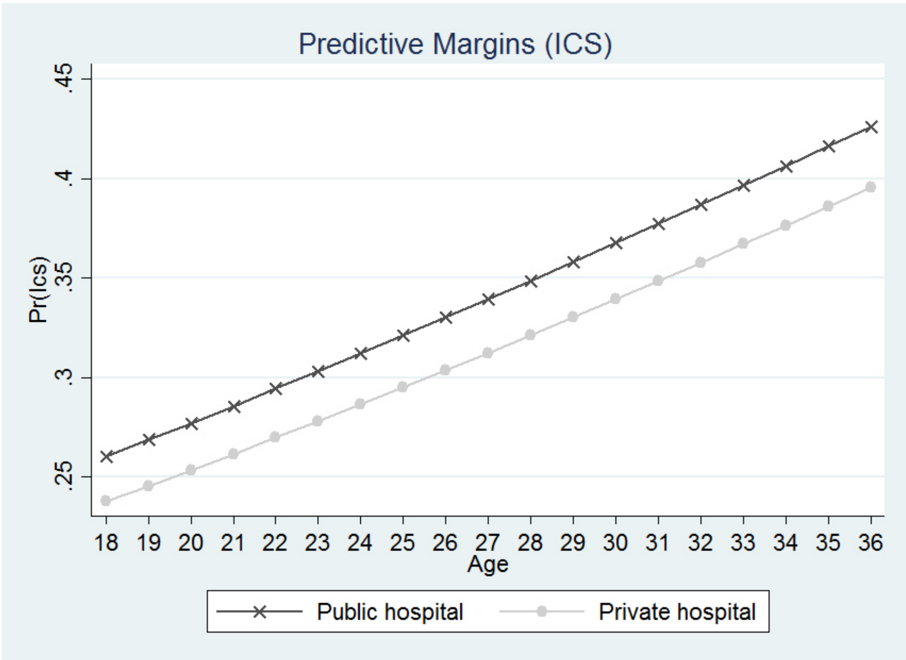
Notes: columns (2), (3) and (4) use different specifications of convenient days defined in the previous Section. Columns (5), (6) and (7) use the same specification for (2), (3) and (4) but adding fixed effects, respectively.

Standard errors in parentheses

$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

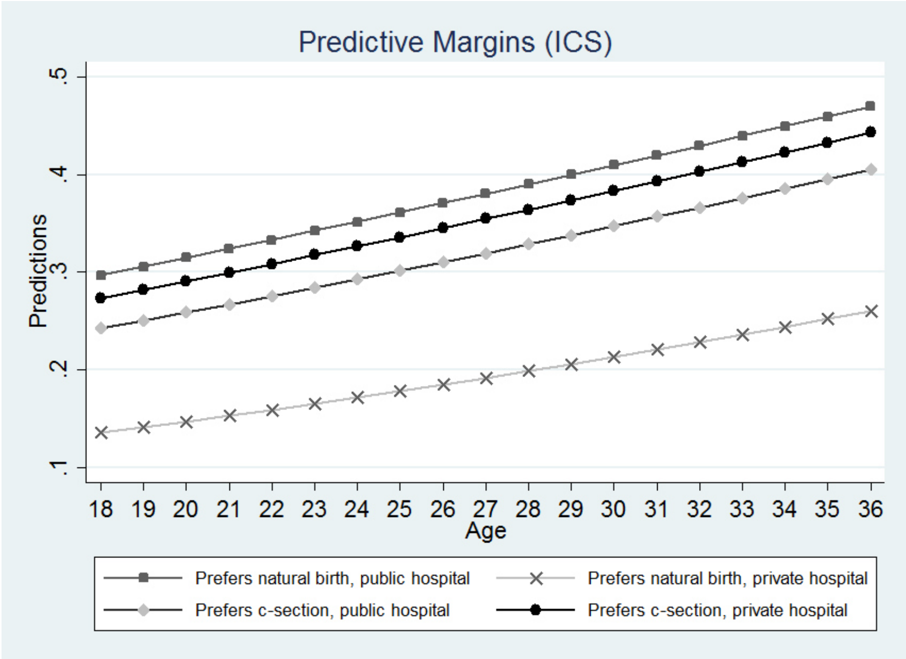
In Table 3.10 we present the average discrete effects from the Probit Model with fixed effects (results are similar without fixed effects). When we observe the effect of convenient and inconvenient days over hospitals, we find some differences. While in public hospitals the probability of having an intrapartum c-section is a bit higher on inconvenient days (34% versus 29% on convenient days), this difference is not statistically significant ($p = 0.425$). However, for private hospitals we observe the opposite: there is a higher probability of having an intrapartum c-section in convenient days (38% against 21% on inconvenient days) and, in this case, the difference is higher and statistically significant ($p = 0.04$).

Figure 3.5: Predicted probability of undergoing an intrapartum c-section



However, even when we would expect that convenience plays a key role in increasing the rate of intrapartum c-section in private hospitals on convenient days, we observe that the effect is on inconvenient days: a woman that delivers in a private hospital, conditionally on not being scheduled a c-section, has a significant lower probability of having an intrapartum c-section on inconvenient days (see Figure 3.6). This result might be due to the fact that more women schedule c-sections in private hospitals, which means that, at this stage of pregnancy, only healthier women are considered.

Figure 3.6: Predicted probability of undergoing an intrapartum c-section



3.7 Discussion/Further analysis

Even when we know that physicians are not paid differently for the mode of delivery, hospitals receive higher refunds. Then, we cannot identify if hospitals exert a pressure on physicians to increase the number of c-sections by sharing with them the premium they get from performing a c-section rather than a natural delivery.

1. We could control for induction in natural births, this is another instrument to speed up a birth process.

2. Is selection after elective c-section the only reason why we observe fewer intrapartum c-sections in private hospitals on holidays/weekends?

3. How many births displaced from inconvenient to convenient day by elective c-sections (fewer admissions in private hospitals on weekend bc of peak of elective c-sections on Friday?)

4. We assume labour has been entered on the same date as date of delivery. This may not be the case. We should also look at the day before the DOB.

5. We could do a better job at excluding other incentives, especially at hospital level. However, so far, we couldn't get more data on how much hospital gains from each procedure, or revenues in general.

3.8 Conclusion

From our study of c-sections in Argentina, we find that there are marked differences in outcomes in the private and public hospitals. A woman's chance of having a scheduled or elective c-section birth is much higher (more than double) if she is admitted to a private than a public hospital. Moreover, if she herself prefers a c-section over a traditional delivery, she is about five times likely to get one in a private hospital than a public one. Among those women who enter labour, a third go on to have an intrapartum c-section in both hospitals. However, behind the similar rates of intrapartum c-sections is a hidden story.

For intrapartum c-sections, the day of labour is crucial to the outcome in private hospitals. On a working day, women are twice more likely to give birth with a c-section than on a weekend or a holiday. In public hospitals, the rates of c-sections do not vary much by day. Though a woman is much less likely to have a c-section in a private hospital on a nonworking day; given that there are twice more working days than nonworking days, and that weekends see fewer women enter labour (perhaps due to the peak of scheduled c-sections on Fridays), the overall rates of intrapartum c-sections are similar for private and public hospitals.

Controlling for preexisting health conditions, age has a slightly positive effect on the chance of having a c-section, but there is a large variance in its impact and as such we do not find it to be significant.

Lastly, we do not find evidence that delivering in a public hospital, where physicians work in teams, is associated with a lower rate of c-sections in comparison with private hospitals, where women are followed up by a single physician. What we do find is that private hospitals schedule more c-sections and also perform more intrapartum c-sections on convenient days.

Appendix A

Proof of Proposition 1.4

We need to show that as δ decreases, the monopolist's optimal strategy is to release a higher share at period one, whenever δ is higher than $\tilde{\delta}$. However, when δ is lower than $\tilde{\delta}$ the monopolist's optimal strategy is to switch and to offer "all-at-once", whatever the value of δ in that range. In order to prove this result, we need some elements first. We assume that $t = 2$.

Lemma A.1. *There exists a threshold, $\delta_{II} \in [0,1]$, such that, whenever $\delta > \delta_{II}$, γ_2^{**} is a monotone increasing function of δ.*

Proof. Given that we cannot represent γ_2^{**} as a function of δ, we use the implicit function theorem to show this result.[1] Recalling our first order condition (Equation 1.24)

$$\frac{\partial \Pi_{\delta}^{II}}{\partial \gamma_2} = g\left(d, \beta, \delta, \gamma_2\right) = \frac{1}{4}\left(\frac{d^2}{\left(1-\gamma_2\right)^2\left(1-\beta\right)} - 1 + \beta\right) + \frac{d^2\delta}{\gamma_2^2\beta^2} = 0$$

γ_2^{**} is the one that solves this equation. We get the effect of δ on γ_2^{**} by using the theorem that says

$$\frac{\partial \gamma_2^{**}}{\partial \delta} = -\frac{\frac{\partial g(\cdot)}{\partial \delta}}{\frac{\partial g(\cdot)}{\partial \gamma_2}}$$

The denominator is negative given that it is the sufficient condition for the existence of a maximum at γ_2^{**} that was already proven. Then, we only need to show that the sign of the numerator is positive. We have that

$$\frac{\partial g\left(\cdot\right)}{\partial \gamma_2} = \left(\frac{d}{\gamma_2\beta}\right)^2$$

[1]The necessary conditions to implement this theorem are satisfied.

that is always positive.

Then, γ_2^{**} decreases as δ decreases, provided that $\gamma_2^{**} > \bar{\gamma_2}^L$, given that from $\bar{\gamma_2}^L$ backwards, piracy is unconditional deterred. When $\gamma_2^{**} = \bar{\gamma_2}^L = \frac{2d}{\beta}$ we have a corner solution that is independent of the value of δ. This threshold is given by δ_{II} defined as

$$\delta_{II} \equiv \frac{(-\beta^2 + \beta + (\beta - 2)d)\,(-\beta^2 + \beta + 3\beta d - 2d)}{(1-\beta)(2d-\beta)^2} \tag{A.1}$$

and it is always between zero and one. □

Then, Lemma A.1 show us that, conditional on piracy being conditional deterred, the monopolist best strategy is to increase the share at period one as the discount factor decreases.

Next, we show how the optimal strategy changes when we are out of the range of conditional deterrence, i.e. unconditional deterrence. When this is the case, the shares of the product are highly differentiated, such that piracy is not a concern at the second period. We show that the monopolist has a binary decision in this situation: either it releases "all-at-once" in the first period ($\gamma_2 = 0$) or it postpones a fixed positive share ($\bar{\gamma_2}^L = \frac{2d}{\beta}$) to the second one. The decision depends on the value of the discount factor.

Lemma A.2. *There exist a threshold, $\delta_{III} \in [0,1]$, such that for values of $\delta < \delta_{III}$, piracy is unconditional deterred and the monopolist's optimal strategy is to release "all-at-once".*

Proof. With a discount factor, Equation 1.26 becomes

$$\Pi_\delta^{III} \equiv \frac{1}{4}\left(d + \gamma_1\,(1-\beta)\right)\left(1 + \frac{d}{\gamma_1\,(1-\beta)}\right) + \frac{\delta\gamma_2}{4} \tag{A.2}$$

We replace $\gamma_1 = 1 - \gamma_2$ and we derive twice Equation A.2 and we get

$$\frac{\partial^2 \Pi_\delta^{III}}{\partial \gamma_2^2} = \frac{d^2}{2(1-\gamma_2)^3(1-\beta)} \tag{A.3}$$

that is always positive. This means that the profit function in the interval $\left[0, \bar{\gamma_2}^L\right]$ is convex, and that the optimal solution is not interior. Then, the optimal solution in this interval is either $\gamma_2 = 0$ or $\gamma_2 = \bar{\gamma_2}^L$ depending on the value of δ. We can easily show that Π^{III} when $\gamma_2 = 0$ is higher than when $\gamma_2 = \bar{\gamma_2}^L$ whenever $\delta < \delta_{III}$ defined as

$$\delta_{III} \equiv \frac{(1-\beta)^2 + d^2\beta + 2d\,(1-\beta)^2}{(2d-\beta)\,(1-\beta)} \tag{A.4}$$

and δ_{III} is in between zero and one. $\square$

From Lemma A.1 and Lemma A.2 we know that there is a discrete jump in the release strategy for different values of δ. However, we still don't know the value of γ_2 at which this jump takes place. There are two natural candidates for this value, either at the corner solution, $\gamma_2 = \bar{\gamma_2}^L$, or at the interior solution, $\gamma_2 = \gamma_2^{**}$.

We can start comparing the values of δ_{III} and δ_{II}. However, given that $\delta_{III} > \delta_{II}$ we don't have any additional information about the location of the jump.[2] It remains to compare Π_δ^{III} when γ_2 is equal to zero, with the optimal value of Π_δ^{II} when $\delta = \delta_{II}$ (at $\gamma_2 = \bar{\gamma_2}^L$)[3]. We easily check that

$$\Pi_{(\gamma_2=0)}^{III} > \Pi_{\delta(\gamma_2=\bar{\gamma_2}^L)}^{II}$$

which tell us that the jump is located at the interior solution of the conditional deterrence. We define the value of γ_2 where the jump takes place as $\tilde{\gamma_2}$. In other words, there exist a threshold, $\tilde{\delta}$, such that for values of δ lower than $\tilde{\delta}$, the monopolist is better off releasing everything in the first period. That threshold is defined where

$$\Pi_{(\gamma_2=0)}^{III} = \Pi_{\tilde{\delta}(\gamma_2=\gamma_2^{**})}^{II}.$$

We can easily check that $\tilde{\delta} > \delta_{II}$, so any value of $\gamma_2 \in [0, \tilde{\gamma_2}]$ do never maximize monopoly profit.

[2]If it were the case that $\delta_{III} < \delta_{II}$, we would have a sufficient condition that the jump is located at $\gamma_2 = \bar{\gamma_2}^L$.

[3]Π_δ^{III} does not depend on δ when $\gamma_2 = 0$.

Appendix B

Proof of Proposition 2.1

We make the proof of Proposition 2.1 in three steps.

Step 1: we calculate the seller's expected income when he participates up to the first stage in the auction. This case is very similar to the previous one but we need to take into account one more bidder that always bid with the lowest signal (who also has a positive probability of finding himself the winner in the case he ties with n bidders at stage 1),

$$\mathbb{E}\left(gain\right)^{\text{shill }(s_1)} = \frac{1}{3^n}\left[\frac{n\left(3+2n\right)}{n+1}\underline{s} + \sum_{j_2=2}^{j_1}\left(\begin{array}{c} j_1 \\ j_2 \end{array}\right)\left\{f\left[\frac{\sum_{z=1}^{2} j_z + 1}{n+1}\right]\left[1+j_2\right] + \sum_{j_3=2}^{j_2}\left(\begin{array}{c} j_2 \\ j_3 \end{array}\right)\left\{f\left[\frac{\sum_{j_z=1}^{3} j_z + 1}{n+1}\right]\right\}\right\}\right]$$

We can easily check that bidding the lowest signal is never be a best response for the seller.[1] Conditional on the legitimate price (without shill bidding) being higher than one, the seller's entry reduces it. Conditional on the legitimate price being equal to one, he has some positive probability of finding himself the winner. In both cases, the seller is worse off.

Step 2: we calculate the seller's incentives of being active in the second stage of the auction.

Once we showed that bidding the lowest signal is never a best response for the seller, we need to find the seller's optimal decision of being active in the second stage of the auction. As we show in Equations 2.2 and 2.3, this decision depends on the number of remaining bidders in the first stage, j_2, but also on the signal distribution. The decision can be summarize in the following function

$$\mathbb{E}\left(gain\right)^{1\text{to}2} = 2n \times \max\left[\frac{3\overline{s}+3n\underline{s}}{4\left(1+n\right)} - \underline{s}, 0\right] + \sum_{j_2=2}^{n} \max\left[2^{j_2}\left(\begin{array}{c} n \\ j_2 \end{array}\right) \times \frac{2^{j}\left(j_2+1\right)\left(\overline{s}-\underline{s}\right) - \overline{s} - j_2\overline{s} - \underline{s} + j_2\underline{s} - 2n\underline{s}}{2^{(j_2+1)}\left(n+1\right)\left(j_2+1\right)}, 0\right].$$

[1]Bidding the lowest signal always decreases the expected price of the object compared to the case of staying out of the auction.

Step 3: we calculate the expected gain of the seller when he participates in the auction.

The only thing we should do is to summarize the previous results together with Lemma 2.4:

$$\mathbb{E}\left(gain\right)^{\text{P}} = \mathbb{E}\left(gain\right)^{\text{shill}} - \mathbb{E}\left(gain\right)^{\text{no shill}}$$

$$\mathbb{E}\left(gain\right)^{\text{P}} = \mathbb{E}\left(gain\right)^{\text{shill }(s_1)} + \mathbb{E}\left(gain\right)^{\text{1to2}} - \mathbb{E}\left(gain\right)^{\text{no shill}}$$

$$\begin{aligned}
\mathbb{E}\left(gain\right)^{\text{P}} \quad = \quad & \tfrac{1}{3^n}\left\{\left(\tfrac{n(3+2n)}{n+1}\right)\underline{s}+\right. \\
& \textstyle\sum_{j_2=2}^{j_1}\begin{pmatrix} j_1 \\ j_2 \end{pmatrix}\left[f\left[\frac{\sum_{z=1}^{2} j_z+1}{n+1}\right][1+j_1]+\sum_{j_i=2}^{j_{i-1}}\begin{pmatrix} j_{i-1} \\ j_i \end{pmatrix}\left\{f\left[\frac{\sum_{j_z=1}^{3} j_z+1}{n+1}\right]\right\}\right]\Bigg\} \\
+ \quad & 2n\times\max\left[\tfrac{3\overline{s}+3n\underline{\underline{s}}}{4(1+n)}-\underline{s},0\right]+\textstyle\sum_{j_2=2}^{n}\max\left[2^{j_2}\begin{pmatrix} n \\ j_2 \end{pmatrix}\times\frac{2^{j}(j+1)(\overline{s}-\underline{s})-\overline{s}-j\overline{s}-\underline{s}+j\underline{s}-2n\underline{\underline{s}}}{2^{(j+1)}(n+1)(j+1)},0\right] \\
- \quad & \tfrac{1}{3^n}\left\{(1+2n)\,\underline{s}+\right. \\
& \textstyle\sum_{j_2=2}^{j_1}\begin{pmatrix} j_1 \\ j_2 \end{pmatrix}\left\{f\left[\frac{\sum_{z=1}^{2} j_z}{2}\right][1+j_1]+\sum_{j_3=2}^{j_2}\begin{pmatrix} j_2 \\ j_3 \end{pmatrix}\left\{f\left[\frac{\sum_{j_z=1}^{3} j_z}{2}\right]\right\}\right\}\Bigg\}
\end{aligned}$$

That is the equation presented in Proposition 2.1.

Appendix C

Tables - Chapter 3

Table C.1: Convenient days

		(1)	(2)	(3)
Normal Week	Tuesday	x	x	x
	Wednesday	x	x	x
	Thursday	x	x	x
	Friday	x	x	x
	Saturday			
	Sunday			
	Monday	x	x	x
Week with long weekend (ex.: on Monday)	Tuesday	x	x	x
	Wednesday	x	x	x
	Thursday	x	x	x
	Friday	x		
	Saturday			
	Sunday			
	Monday			
Week with mid-week holiday (ex.: on Wednesday)	Tuesday	x		x
	Wednesday			
	Thursday	x	x	x
	Friday	x	x	x
	Saturday			
	Sunday			
	Monday	x	x	x

Figure C.1: Elective c-section births by the days of the week

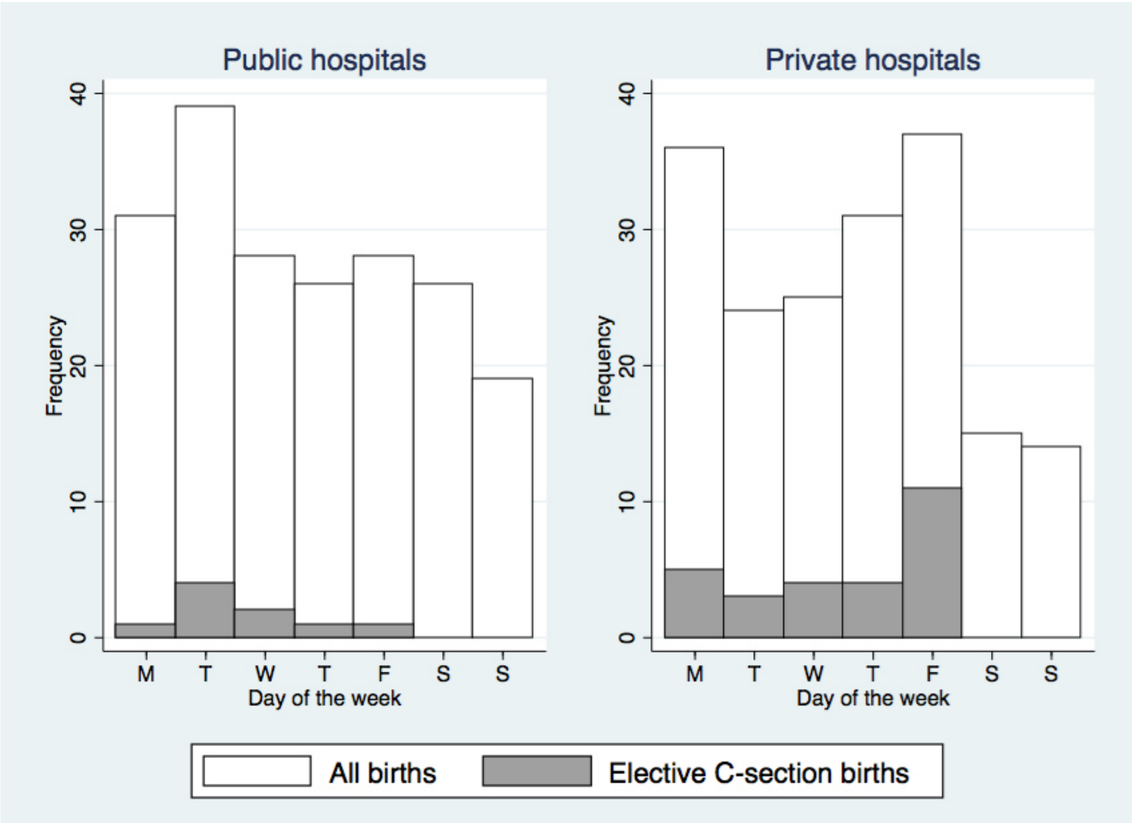
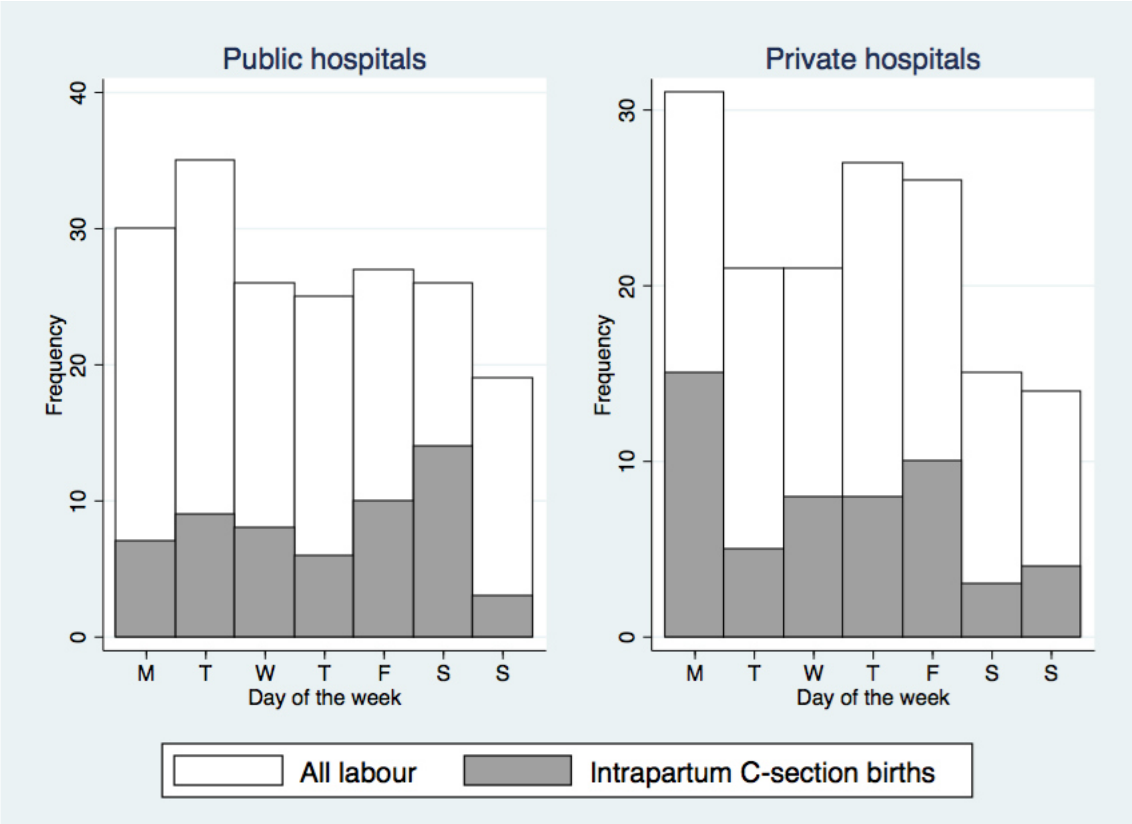


Figure C.2: Intrapartum c-section births by the days of the week



The difference between 'all labour' and 'intrapartum c-section births' are the natural deliveries.

Figure C.3: Predicted probability of undergoing a c-section

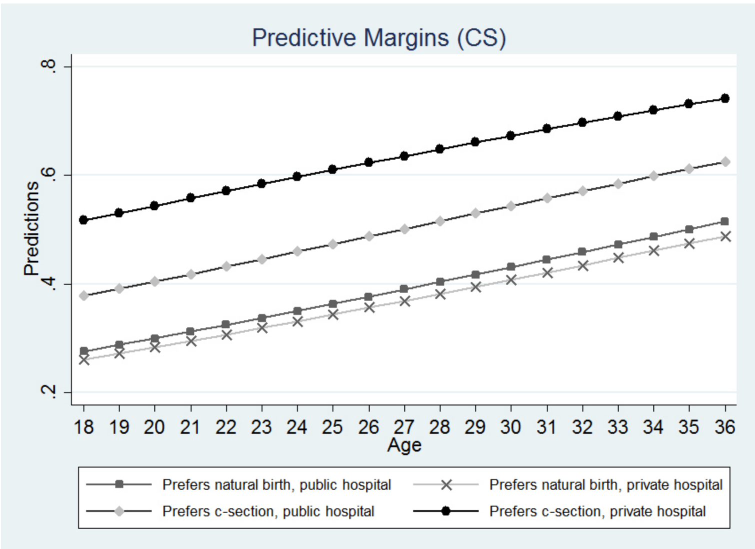


Table C.2: Number and type of deliveries per hospital

Type	Name	Mode of Delivery CS	VD	Total
Public	Hospital Magdalena V. de Martínez	24	53	77
	Hospital Materno Infantil Dr. Carlos Gianantonio	39	54	93
	Hospital Comunal de Tigre	4	22	26
	Other public	1	0	1
	Subtotal	*68*	*129*	*197*
Private	Hospital Italiano de Buenos Aires	43	46	89
	Centro de Educación Médica e Investigaciones Clínicas "Norberto Quirno" (CEMIC)	17	20	37
	Hospital Británico de Buenos Aires	20	33	53
	Others	0	3	3
	Subtotal	*80*	*102*	*182*
	At home	0	1	1
	Total	**148**	**232**	**380**

Figure C.4: Predicted probability of undergoing a c-section

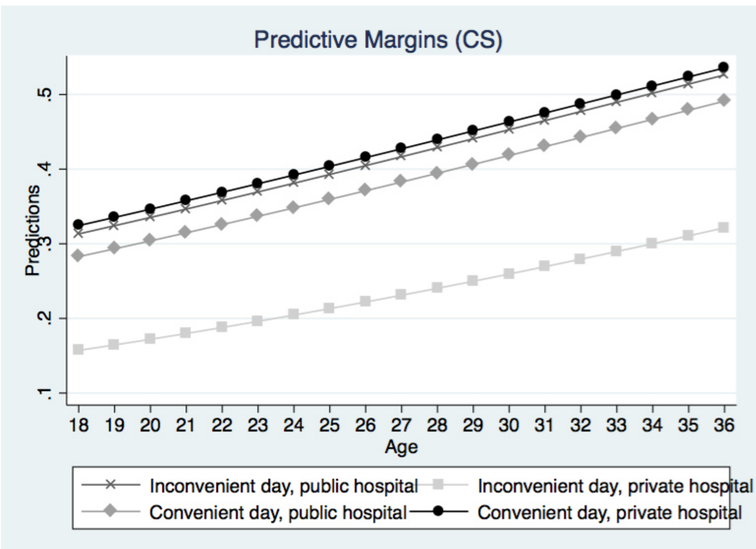


Table C.3: Mode of delivery (intrapartum)

Mode of delivery	Public hospital	Private hospital	Total
VD	69.7%	65.8%	233
ICS	30.3%	34.2%	110
Total	188	155	343

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