

Research Article

Entry Regulation under Asymmetric Information about Demand

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We investigate how an incumbent firm can use the regulatory policy about entry and the informational advantage to protect his market position. This question is studied through the construction of a signalling game where we assume that the regulator has less information about demand than the firms. We conclude that there is a pooling equilibrium and partially separating equilibria in which entry is deterred and, if demand is high, there will be insufficient entry. The final effect on welfare depends on the tradeoff between short-run benefits (lower price) and long-run losses (weaker competition).

1. Introduction

Asymmetric information is an important feature of the relationship between regulated firms and regulatory authorities. When firms have more information than the regulatory authorities, it might be expected that they use their advantage to influence the regulator's decision to their own benefit. Commonly, the regulatory authority perceives its lack of information about the market or the firm characteristics, but it is under these constraints that it has to define the regulatory policy. This is the general context of this paper. The particular question studied is related to entry regulation under asymmetric information conditions. We study a benevolent regulator who has to decide upon the number of new firms that are allowed to enter an industry not regulated in other dimensions, such as prices. The regulator's decision about the maximum number of firms that can enter the market is a central feature of entry regulation policy.

The tendency for liberalization and deregulation of several utilities observed in most European countries in the last few decades has reduced the direct intervention of the authorities in the definition of the number of firms that participate in each industry. The air transport sector is an example of this trend. However, we can advance several arguments, either theoretical or resulting from empirical observation, that support the present importance of entry regulation. In some sectors, a large number of firms might

decrease social welfare, because of scale economies, network externalities, or entry costs but, from an individual standpoint, the industry can be attractive. This is the Excess Entry Theory applied by Mankiw and Whinston [1] to oligopoly markets. Additionally, in recently privatized industries, with partial liberalization, entry is gradual and controlled. This is happening, for instance, in mobile telecommunications where, due to the scarcity of a vital input, the radio spectrum, new firms need the regulator's approval to enter. Before conceding licenses, regulators define the number of firms that can operate in the industry. The policy of the British regulator in the mobile segment of the telecommunications industry provides an example of entry regulation. In 1985, the regulator authorized the entry of two firms (Cellnet and Vodafone), following the model applied in the United States for the mobile telephone market. In 1991, two further mobile operators were licensed with the restriction of no further entry before 2005 [2, page 323]. Also, we can give a broader interpretation of entry regulation and consider that it means the public authority's actions that influence the attractiveness of entry. In this context the public authority's decision is about the intensity of the entry promotion policy, as happens, for instance, in the definition of the remedies that accompany merger authorizations. Then, the motivation for entry regulation is the promotion of entry.

In this paper we study how the incumbent firm might use his private information to influence the regulator's entry

decision. We assume that the firms have private information about market demand based on the following arguments. Firms have closer and more frequent contact with their customers than the regulatory authority, which necessarily has a more distant position. Firms have superior knowledge of the quality of the products, and of the expected reaction of the customers to that same quality in terms of the quantity demanded at any price. Finally, firms frequently devote significant resources to marketing studies to improve their perception of demand features [3].

We also assume that, although the regulator has less information than the firms about demand size, she can observe the market price in the period before regulation is implemented. Then, the regulator takes the price as a signal of demand size. Knowing the regulator's behavior, the incumbent firm might strategically define the price in the period before regulation is implemented. The methodology used to study the firms' and regulator's decisions involves the construction of a signalling game in which the regulator is the uninformed player.

From the signalling model developed we conclude that, in equilibrium, the incumbent firm chooses a low price in the period before regulation, whether demand is low or high (we consider here as of particular interest a pooling and a partially separating equilibria). The purpose of this strategy is to signal a low demand and thus to induce the regulator to allow the entry of a small number of firms. Then, the incumbent firm uses the entry regulation to protect his market from strong competition. These results are useful in drawing the regulator's attention to the potential strategic behavior of the incumbent firm in the preregulation period.

The signalling model developed in the paper is related to the literature on entry deterrence with asymmetric information, in particular with the model of Milgrom and Roberts [4]. In fact, we develop a signalling model inspired in the Milgrom and Roberts [4], where the informed player (the incumbent firm) conveys information about the demand size to the uninformed player (the regulator) aiming to manipulate the regulator's decision about entry. Another strand of the literature on entry deterrence is the signal jamming [5], in which the informed player bears some costs in order to keep secret his private information (a secret price cut is the example given by Fudenberg and Tirole [5]).

Milgrom and Roberts model, however, does not consider a regulated industry. From this perspective, the analysis of Kim [6] is closer to our model as it deals specifically with entry regulation under asymmetric information. Nevertheless, our approach departs from Kim's model as we assume asymmetric information about demand, instead of private information about costs. Mankiw and Whinston's [1] model about excess entry inspired the general approach developed here. Prior to the article of Mankiw and Whinston, the idea of excess entry in a homogenous market was studied by Weizsäcker [7], Perry [8], Suzumura and Kiyono [9], and Riordan [10].

The structure of the paper is the following. Section 2 describes the signalling model and Section 3 discusses the equilibria. Section 3.1 proves the existence of a pooling equilibrium; Section 3.2 discusses other equilibria in pure

strategies; Section 3.3 discusses the existence of partial separating equilibria; Section 3.4 gives an interpretation of the pooling equilibrium and Section 3.5 presents an illustration of the pooling equilibrium. Finally, Section 4 presents the main conclusions.

2. The Model

Mankiw and Whinston [1] showed that in an industry with homogeneous product, fixed costs of entry and where "the equilibrium output per firm declines as the number of firms grows" [1, page 49], free entry implies excess entry from a social welfare point of view.

We show that the introduction of asymmetric information and entry regulation in the Mankiw and Whinston framework allows the incumbent firm to manipulate the regulator's decision about entry. We assume that the regulator does not know the demand size, in spite of knowing the general features of the demand. Nevertheless, the regulator supposes, a priori, that demand size can be low (D^L) or high (D^H). Under both cases we consider that the Mankiw and Whinston's assumptions are valid.

Assumption 1. The aggregate equilibrium output after entry increases with the number of entrants and approaches some finite bound.

Assumption 2. Each firm's equilibrium output falls with entry (business stealing effect).

Assumption 3. The equilibrium price after entry is not below marginal cost.

Because of the excess entry problem that arises with free entry under the above assumptions, the regulator defines the maximum number of firms that can enter the industry. We assume that if the regulator had perfect knowledge of the demand size, it would authorize the entry of $n^L - 1$ new firms if demand was low, or $n^H - 1$ new firms if demand was high with $n^L < n^H$. The numbers of firms n^L and n^H maximize the social welfare indicator when demand is low or high, respectively. Considering that $W^i(n)$ represents the social welfare indicator when demand is of type i ($i = L, H$) and there are n firms in the market, we have the following conditions: (i) $W^L(n^L) > W^L(n^H)$ and (ii) $W^H(n^L) < W^H(n^H)$.

Notice that in this model the entrants' decisions are not strategic, as the entrants firms are always willing to enter the market. This is ensured by the Mankiw and Whinston result that the free entry number of firms is higher than the social optimal number of firms.

Before deciding how many new firms can enter, the regulator observes the price defined by the incumbent firm and considers it as a signal of demand size. The incumbent firm knows the regulator's decision process so he strategically chooses the price in the preregulation period.

In this framework we assume that the regulator is not able to commit to an entry policy. Otherwise, we would need to consider a different framework where the

regulator, previously to the definition of the first period price, announces the entry policy. Then, the problem would be solved within the standard incentive contract theory, considering, for instance, an adverse selection model.

2.1. Time of the Game. The time of the game is the following.

- (i) At stage zero, Nature selects demand size, D^L or D^H with probability r and $1 - r$ (with $0 < r < 1$), respectively. Afterwards, the incumbent firm observes Nature's choice. We assume that the demand size does not change in the subsequent stages of the game.
- (ii) At stage one, the incumbent firm chooses the price (the first period's price).
- (iii) At stage two, new firms wish to enter the market regardless of demand size. However, the regulator defines the maximum number of new firms in order to avoid excess entry. This number of firms is the one that maximizes the expected value of social welfare. Finally, the oligopolist interaction between the firms leads to the establishment of another price (the second period's price).

2.2. Payoffs. The regulator's payoff is measured by social welfare (defined as the sum of consumer surplus and firms' profits) in the second period; the entrants' payoff is given by their profit in the second period and the incumbent firm's payoff is the sum of its profits for the two periods. Notice that as the second period summarizes future competition over repetitions of the game, then the profits of this period correspond to the discount sum of future profits. It is important to emphasize that the relevant payoff for the regulator's decision is defined considering only the second period's results. This happens because the regulator's decision about entry is taken at the beginning of the second stage. This assumption can be justified in cases where the regulator is a new body that initiates her activity at the second period. However, from the consumers' perspective, the outcomes of both periods are important. Therefore, to evaluate the model's results (which is done in Section 3.4) we define a social welfare measure sensitive to the results of both periods.

In the description of the signalling game we assume the following terminology.

- (a) $\pi_1^i(P^k)$ represents the monopolist profit in the first period when demand is of type i and the first period's price is P^k ($k = L, H$). If $i = k$, the monopolist has the maximum profit; if $i \neq k$, the monopolist is giving up some profit.
- (b) $\pi_2^i(n^j)$ represents the incumbent firm's profit in the second period when demand is of type i and there are n^j firms in the market. If $i = j$ social welfare is maximized.
- (c) The parameters p and q represent the regulator's update beliefs about the demand size after observing the price. Hence, $p(q)$ represents the probability of low demand if the first period's price is P^H (P^L).

- (d) The strategies of the players (incumbent firm and regulator) have to specify how they behave in every possible scenario in which they are called to act. Therefore, the players' strategies are represented by a pair of values. For the incumbent firm the pair (P^x, P^y) means that he chooses price P^x if demand is D^L and he chooses price P^y if demand is D^H . For the regulator the pair (n^w, n^z) means that the regulator chooses to allow the entry of $n^w - 1$ new firms if the incumbent firm has chosen a price equal or below P^x , and the regulator chooses to allow the entry of $n^z - 1$ new firms otherwise.

3. Equilibrium

3.1. The Pooling Perfect Bayesian Equilibrium. The signalling game has a Pooling Perfect Bayesian Equilibrium described by Proposition 1.

Proposition 1. *The strategies and beliefs represented by $[(P^L, P^L), (n^p, n^h), (q = r, p = 0)]$ are a Perfect Bayesian Equilibrium if*

$$\pi_1^H(P^L) + \pi_2^H(n^p) \geq \pi_1^H(P^H) + \pi_2^H(n^h). \quad (1)$$

The Pooling Perfect Bayesian Equilibrium can be described in the following way: whatever the demand size, the incumbent firm chooses the price that maximizes the profit when demand is low. The objective of this strategy is to keep unclear to the regulator whether demand size is enough to accommodate many new firms. The regulator observes this price and updates her beliefs: the probability of low demand if the observed price is P^L becomes r and the probability of low demand if the observed price is P^H becomes $p = 0$. Then, the regulator allows the entry of $n^p - 1$ firms if the price is P^L , or $n^h - 1$ firms if the price is P^H . At the equilibrium described, the incumbent firm strategically uses the entry regulation and the private information about demand to induce the regulator to protect his market from competition.

The existence of this Pooling Perfect Bayesian Equilibrium requires the verification of condition (1) which has an intuitive explanation. We can interpret condition (1) by saying that the limit price strategy is attractive to the incumbent firm when demand is D^H ; that is, the incumbent firm prefers to lose some profit in the first period and share the market with few firms in the second period, than to maximize the profit in the first period and share the market with many firms in the second period.

Proof of Proposition 1. We prove Proposition 1 in three steps. First, we prove that the best regulator's response after observing the price P^L is to choose n^p . Second, we prove that (P^L, P^L) is the incumbent firm's best decision considering that (n^p, n^h) and $(q = r, p = 0)$ are the regulator's equilibrium strategy and the updated beliefs, respectively. Finally, we prove that the best regulator's response after observing the price P^H is to choose n^h , given (P^L, P^L) and $(q = r, p = 0)$.

First step: if (P^L, P^L) is an equilibrium strategy for the incumbent firm, then the regulator's information set corresponding to P^L is on the equilibrium path. Hence, the regulator's belief is updated by Bayes' rule and the incumbent firm's strategy, being $q = r$, the prior belief. This means that after observing the price P^L , the regulator has no additional information about demand size. Then, the regulator chooses the value of n that maximizes the expected value of welfare represented by $E[W(n)] = rW^L(n) + (1 - r)W^H(n)$. Let us represent this value by n^P , such that

$$\frac{dE[W(n)]}{dn} = 0 \implies n = n^P(r), \quad n^L < n^P < n^H. \quad (2)$$

Notice that n^P is an intermediate value between n^L and n^H , and depends on r (the prior belief). It is expected that n^P decreases with r . These conclusions are obtained for all pooling strategies for the incumbent firm, as the above demonstration does not depend on the value of p^L , but only depends on the conclusion that the update belief (p) is equal to the priori belief (r).

Second step: to determine if the incumbent firm is willing to choose P^L whatever the demand size, we need to compare the payoffs of choosing P^L with the payoffs of choosing P^H . To make this comparison, we must specify how the regulator would react to P^H . Notice that the incumbent firm's payoffs of choosing P^L are $\pi_1^L(P^L) + \pi_2^L(n^P)$ when demand is D^L and $\pi_1^H(P^L) + \pi_2^H(n^P)$ when demand is D^H , because we have already proved that the regulator's optimal response to P^L is n^P .

If the regulator's response to P^H is n^P , the incumbent firm's payoff is $\pi_1^L(P^H) + \pi_2^L(n^P)$ when demand type is D^L , which is below the payoff corresponding to P^L , $\pi_1^L(P^L) + \pi_2^L(n^P)$. When demand type is D^H the incumbent firm's payoff is $\pi_1^H(P^H) + \pi_2^H(n^P)$, which is greater than the payoff corresponding to P^L , $\pi_1^H(P^L) + \pi_2^H(n^P)$. Then, if the regulator's response to P^H is n^P , the strategy (P^L, P^L) is not a best response for the incumbent firm.

On the contrary, if the regulator's response to P^H is n^H , the incumbent's payoff is $\pi_1^L(P^H) + \pi_2^L(n^H)$ when demand type is D^L , which is below the payoff corresponding to P^L , $\pi_1^L(P^L) + \pi_2^L(n^P)$. When demand type is D^H the incumbent firm's payoff is $\pi_1^H(P^H) + \pi_2^H(n^H)$, which is below the payoff corresponding to P^L if (1) holds.

Then, if there is an equilibrium in which the incumbent firm's strategy is (P^L, P^L) the regulator's response to P^H must be n^H , because, under condition (1), we conclude that choosing P^L is always the best strategy for the incumbent firm. Then, by now, we assume that the regulator's strategy is (n^P, n^H) .

Third step: finally, we must consider the regulator's belief in the information set corresponding to P^H and the optimality of choosing n^H given this belief. At the second step we need to assume that the regulator's decision after P^H is n^H in order to obtain the result that the firm's choice of P^L leads to higher payoffs than the choice of P^H , regardless of demand size. Now, we must prove that n^H is the best regulator's decision after observing P^H . If $p = 0$ then choosing n^H , as a response to P^H is optimal for the regulator as this is the value that maximizes the expected welfare. \square

3.2. *Other Pure Strategy Equilibria of the Signalling Game.* The strategy (P^L, P^L) , and the corresponding Perfect Bayesian Equilibrium, plays a central role in this paper. This happens because we eliminate from the analysis all other pure strategies that could constitute a Perfect Bayesian Equilibrium with the following justifications.

First, it is important to notice that even with no threat of entry, the incumbent firm would never choose prices greater than P^L if demand is D^L , and/or prices greater than P^H if demand is D^H . Hence, with the possibility of entry, the incumbent firm does not consider prices above the optimal levels.

Second, the strategy (P^L, P^H) cannot be a Separating Perfect Bayesian Equilibrium given (n^L, n^H) and $(q = 1, p = 0)$ if condition (1) is true.

Proof. If (P^L, P^H) is an equilibrium strategy, both regulator's information sets are on the equilibrium path. Hence, the beliefs are updated by Bayes' rule and the incumbent firm's strategy. From the strategy (P^L, P^H) we know that $\text{Prob}(P^L | D^L) = 1$ and $\text{Prob}(P^H | D^H) = 1$. By definition we know that

- (i) $\text{Prob}(P^L) = \text{Prob}(P^L | D^L) \cdot \text{Prob}(D^L) + \text{Prob}(P^L | D^H) \cdot \text{Prob}(D^H) = r$,
- (ii) $\text{Prob}(P^H) = \text{Prob}(P^H | D^L) \cdot \text{Prob}(D^L) + \text{Prob}(P^H | D^H) \cdot \text{Prob}(D^H) = 1 - r$,
- (iii) $\text{Prob}(D^L, P^L) = \text{Prob}(P^L | D^L) \cdot \text{Prob}(D^L) = \text{Prob}(D^L | P^L) \cdot \text{Prob}(P^L)$,
- (iv) $\text{Prob}(D^L, P^H) = \text{Prob}(P^H | D^L) \cdot \text{Prob}(D^L) = \text{Prob}(D^L | P^H) \cdot \text{Prob}(P^H)$.

Then,

$$p = \text{Prob}(D^L | P^H) = \frac{\text{Prob}(P^H | D^L) \cdot \text{Prob}(D^L)}{\text{Prob}(P^H)} = 0, \quad (3)$$

$$q = \text{Prob}(D^L | P^L) = \frac{\text{Prob}(P^L | D^L) \cdot \text{Prob}(D^L)}{\text{Prob}(P^L)} = 1. \quad (4)$$

Given these updated beliefs, the regulator's best response is (n^L, n^H) because

- (i) if P^L and n^L , the regulator's payoff is $W^L(n^L)$; if P^L and n^H , the regulator's payoff is $W^L(n^H) < W^L(n^L)$
- (ii) if P^H and n^L , the regulator's payoff is $W^H(n^L)$; if P^H and n^H , the regulator's payoff is $W^H(n^H) > W^H(n^L)$.

Now, we must check whether (P^L, P^H) is a best response to (n^L, n^H) . When demand type is D^L and the incumbent firm's choice is P^L , the regulator's decision is n^L . Then, the incumbent firm's payoff is $\pi_1^L(P^L) + \pi_2^L(n^L)$, which is above the payoff of choosing P^H , $\pi_1^L(P^H) + \pi_2^L(n^H)$. Hence, the incumbent firm has no incentive to deviate from the choice of P^L when demand is D^L .

When demand type is D^H and the incumbent firm's choice is P^H , the regulator's decision is n^H . Then, the incumbent firm's payoff is $\pi_1^H(P^H) + \pi_2^H(n^H)$ which, by condition (1), is below the payoff corresponding to P^L .

Hence, when demand type is D^H , the firm has an incentive to deviate from the decision P^H . Therefore, (P^L, P^H) cannot belong to a Perfect Bayesian Equilibrium with the verification of condition (1). \square

Therefore, (P^L, P^H) only belongs to a separating equilibrium in which the incumbent firm reveals the demand size if condition (1) is not true. This means that if the limit price strategy is not attractive when demand is high, the firm prefers to receive the monopoly profits of the first period and share the market in the second period. Rasmusen [11, page 286] labels this separating equilibrium as nonstrategic because the incumbent firm chooses the price that maximizes the profit without caring about entry regulation. This separating equilibrium only occurs if the value of being a monopolist is not “too” high and, therefore, the incumbent firm is not interested in giving up some of the first period’s profits to maintain the monopoly position.

Third, the existence of a pooling equilibrium with (P^1, P^1) and $P^1 < P^L$ requires not only condition (1) but also the verification of a similar condition similar to (1) applied to the low demand. Also, under these conditions, there are multiple equilibria because P^1 is not unique. Furthermore, all the pooling equilibria with (P^1, P^1) and $P^1 < P^L$ imply payoffs for the incumbent firm below the corresponding equilibrium payoffs with (P^L, P^L) , if the profit function in the first period is monotonically increasing with price for $P < P^H$ when D^H . This is an additional reason for excluding these cases from the analysis. The description of the equilibria mentioned is presented in Appendix A.

Fourth, so that strategies (P^1, P^H) with $P^1 < P^L$ are part of a separating Perfect Bayesian Equilibrium they have to meet certain conditions that make this equilibria less relevant. Consider the profile $[(P^1, P^H), (n^L, n^H), (q = 1, p = 0)]$ with $P^1 < P^L$. If (P^1, P^H) with $P^1 < P^L$ is an equilibrium strategy, then $q = 1$ and $p = 0$. With these updated beliefs the best regulator’s response is the strategy (n^L, n^H) . It is necessary to verify whether (P^1, P^H) is a best incumbent firm’s response to (n^L, n^H) . If D^L and P^1 , the incumbent firm payoff is $\pi_1^L(P^1) + \pi_2^L(n^L)$, which must be compared with $\pi_1^L(P^H) + \pi_2^L(n^H)$. If D^H and P^H , the incumbent firm’s payoff is $\pi_1^H(P^H) + \pi_2^H(n^H)$, which must be compared with $\pi_1^H(P^1) + \pi_2^H(n^L)$. Then, the existence of a Perfect Bayesian Equilibrium with (P^1, P^H) and $P^1 < P^L$ requires that $\pi_1^L(P^1) + \pi_2^L(n^L) > \pi_1^L(P^H) + \pi_2^L(n^H)$ and $\pi_1^H(P^H) + \pi_2^H(n^H) > \pi_1^H(P^1) + \pi_2^H(n^L)$. However, if these conditions are met we have multiple equilibria because there are multiple values of P^1 that verify the conditions described. Additionally, we can observe that, for all the equilibria with (P^1, P^H) and $P^1 < P^L$, the equilibrium payoffs of the incumbent firm are always below the equilibrium payoffs corresponding to the strategy (P^L, P^L) . Notice that the equilibrium payoffs corresponding to (P^L, P^L) are (a) $\pi_1^L(P^L) + \pi_2^L(n^L)$ if D^L ; (b) $\pi_1^H(P^L) + \pi_2^H(n^L)$ if D^H . The equilibrium payoffs corresponding to (P^1, P^H) are (c) $\pi_1^L(P^1) + \pi_2^L(n^L)$ if D^L ; (d) $\pi_1^H(P^H) + \pi_2^H(n^H)$ if D^H . As (a) $>$ (c) and (b) $>$ (d) by condition (1), the equilibrium with (P^L, P^L) dominates the equilibria with (P^1, P^H) and $P^1 < P^L$. Then, as the strategy (P^L, P^L) dominates those with

(P^1, P^H) for all $P^1 < P^L$ we eliminate these strategies from our analysis.

Fifth, strategies (P^L, P^2) with $P^L < P^2 < P^H$ cannot belong to a Separating Perfect Bayesian Equilibrium, even with (n^L, n^H) , $q = 1$ and $p = 0$, because when demand type is D^H the incumbent firm has no incentive to choose $P^2 < P^H$. For any $P > P^L$, the regulator allows the entry of n^H firms, so the best firm’s response is to maximize the profit in the first period which implies the price P^H . Then, we have the strategy (P^L, P^H) explained above.

3.3. Partial Separating Equilibria of the Signalling Game.

In this section we prove the existence of multiple partial separating equilibria in the signalling game under analysis. (We thank an anonymous referee for the suggestion to study partial separating equilibria.) In this signalling model, a partial separating incumbent’s strategy represents a situation where the incumbent firm does not entirely reveal the demand size, on the contrary of what happens with the separation strategy (P^L, P^H) , because there is uncertainty about the incumbent’s decision. But, at the same time, the incumbent firm does not fully sacrifice the period’s one profits when demand is D^L , as it happens with the pooling strategy (P^L, P^L) , as it is possible to choose P^H when demand is high. The partial separating strategy for the incumbent firm can be described as follows: if demand is D^L the incumbent firm chooses the pure strategy P^L ; if, on the contrary, demand is D^H , the incumbent firm chooses P^L with probability α and chooses P^H with probability $1 - \alpha$. We represent this partial mixed strategy for the incumbent firm as $(P^L, (\alpha, 1 - \alpha))$. As the regulator is aware that observing P^L does not necessary mean that demand is D^L , the regulator also plays the following mixed strategy: if the price is P^L the regulator chooses, with probability β , the number of firms that maximize the expected payoffs (represented by n^{PS}), with probability δ chooses n^L and with probability $1 - \beta - \delta$ chooses n^H ; if the price is P^H the regulator chooses n^H . We represent the regulator’s strategy as $((\beta, \delta, 1 - \beta - \delta), n^H)$. More intuitively, we could consider that the regulator does not have a mixed strategy, and after observing P^L always chooses the number of firms that maximize the expected value of her payoff (n^{PS}). This possibility is just the particular case where $\beta = 1$ and $\delta = 0$. Then, we prove the following assumption.

Proposition 2. *The strategies and beliefs represented by the profile $[(P^L, (\alpha, 1 - \alpha)), ((\beta, \delta, 1 - \beta - \delta), n^H), (q, p = 0)]$ with $q = r/r + \alpha(1 - r)$ are a Perfect Bayesian Equilibrium for some values of the parameters if (1) holds.*

Proof. First, we have to calculate the updated beliefs by Bayes’ rule given the incumbent’ strategy $(P^L, (\alpha, 1 - \alpha))$ as, with this strategy, both regulator’s information sets are on the equilibrium path. Reminding that the prior beliefs are $\text{Prob}(D^L) = r$ and $\text{Prob}(D^H) = 1 - r$, we have $\text{Prob}(P^L | D^L) = 1$; $\text{Prob}(P^L | D^H) = \alpha$; $\text{Prob}(P^H | D^H) = 1 - \alpha$; $\text{Prob}(P^H | D^L) = 0$. Also, we know that $\text{Prob}(P^L) = r + \alpha(1 - r)$; $\text{Prob}(P^H) = (1 - \alpha)(1 - r)$. From these values we verify that, given the incumbent’s strategy $(P^L, (\alpha, 1 - \alpha))$, the probability of

having P^L is now greater than r and the probability of having P^H is lower than $1 - r$. Therefore, the updated beliefs are

$$q = \text{Prob}(D^L | P^L) = \frac{r}{r + \alpha(1-r)}, \quad p = \text{Prob}(D^L | P^H) = 0. \quad (5)$$

With these updated beliefs we have to prove that the strategies are best replies. \square

Given the incumbent's strategy $(P^L, (\alpha, 1 - \alpha))$ and the updated beliefs, we prove that $((\beta, \delta, 1 - \beta - \delta), n^H)$ is a best reply for the regulator.

Notice that, if the regulator observes P^H , she immediately concludes that demand is D^H (as $\text{Prob}(D^H | P^H) = 1$) and then decides to authorize $n^H - 1$ new firms.

Alternatively, if the price is P^L , the regulator is not sure about the demand size. Then, she plays the mixed strategy $(\beta, \delta, 1 - \beta - \delta)$. To characterize the expected regulator's payoff we must consider the eight combination according to the incumbent firm and regulator decisions

- (1) Demand is D^L and the incumbent firm chooses P^L (which happens with $\text{Prob}(D^L | P^L)$), and the regulator chooses n^{PS} (which happens with probability β).
- (2) Demand is D^L and the incumbent firm chooses P^L (which happens with $\text{Prob}(D^L | P^L)$), and the regulator chooses n^L (which happens with probability δ).
- (3) Demand is D^L and the incumbent firm chooses P^L (which happens with $\text{Prob}(D^L | P^L)$), and the regulator chooses n^H (which happens with probability $1 - \beta - \delta$).
- (4) Demand is D^L and the incumbent firm chooses P^H (which happens with $\text{Prob}(D^L | P^H)$) and the regulator chooses n^H (which happens with probability 1).
- (5) Demand is D^H and the incumbent firm chooses P^L (which happens with $\text{Prob}(D^H | P^L)$) and the regulator chooses n^{PS} (which happens with probability β).
- (6) Demand is D^H and the incumbent firm chooses P^L (which happens with $\text{Prob}(D^H | P^L)$) and the regulator chooses n^L (which happens with probability δ).
- (7) Demand is D^H and the incumbent firm chooses P^L (which happens with $\text{Prob}(D^H | P^L)$) and the regulator chooses n^H (which happens with probability $1 - \beta - \delta$).
- (8) Demand is D^H and the incumbent firm chooses P^H (which happens with $\text{Prob}(D^H | P^H)$) and the regulator chooses n^H (which happens with probability 1).

Then, the regulator's expected payoff is given by

$$\begin{aligned} E[W(n)] = & \text{Prob}(D^L | P^L) * \beta * W^L(n) \\ & + \text{Prob}(D^L | P^L) * \delta * W^L(n^L) \\ & + \text{Prob}(D^L | P^L) * (1 - \beta - \delta) * W^L(n^H) \\ & + \text{Prob}(D^L | P^H) * 1 * W^L(n^H) \\ & + \text{Prob}(D^H | P^L) * \beta * W^H(n) \\ & + \text{Prob}(D^H | P^L) * \delta * W^H(n^L) \\ & + \text{Prob}(D^H | P^L) * (1 - \beta - \delta) * W^H(n^H) \\ & + \text{Prob}(D^H | P^H) * 1 * W^H(n^H) \end{aligned} \quad (6)$$

which is equivalent to

$$\begin{aligned} E[W(n)] = & \beta \left[\frac{r}{r + \alpha(1-r)} W^L(n) + \frac{\alpha(1-r)}{r + \alpha(1-r)} W^H(n) \right] \\ & + \frac{r}{r + \alpha(1-r)} \delta W^L(n^L) \\ & + \frac{r}{r + \alpha(1-r)} (1 - \beta - \delta) W^L(n^H) \\ & + \frac{\alpha(1-r)}{r + \alpha(1-r)} \delta W^H(n^L) \\ & + \frac{\alpha(1-r)}{r + \alpha(1-r)} (1 - \beta - \delta) W^H(n^H) + W^H(n^H). \end{aligned} \quad (7)$$

Notice that, in the above definition, only the first part of the right hand side depends on n , then only this part is important to define the number of firms that maximize the expected value of the regulator's payoff (n^{PS}). From the first order condition we obtain:

$$\frac{dE[W(n)]}{dn} = 0 \implies n = n^{PS}, \quad n^L < n^{PS} < n^H. \quad (8)$$

Then, with $n = n^{PS}$, $((\beta, \delta, 1 - \beta - \delta), n^H)$ is a best reply for the regulator.

Notice that, as in the pooling equilibrium, n^{PS} is an intermediate value between n^L and n^H , that depends on r and also on α . Additionally, we can verify that $n^{PS} < n^P$, meaning that with the partial separating strategy, the number of firms authorized by the regulator is closer to n^L than the corresponding number with the pooling strategy. (In the regulator's problem with the partial separating strategy the weight given to $W^L(n)$ is greater than the one given in the regulator's problem with the pooling strategy, as $r/(r + \alpha(1-r)) > r$, therefore $n^{PS} < n^P$.)

Finally, we have to prove that $(P^L, (\alpha, 1 - \alpha))$ is an incumbent firm's best reply given $((\beta, \delta, 1 - \beta - \delta), n^H)$ and the updated beliefs.

Let us assume D^L . If the incumbent firm chooses P^L his payoff is $\pi_1^L(P^L) + [\beta\pi_2^L(n^{PS}) + \delta\pi_2^L(n^L) + (1 - \beta - \delta)\pi_2^L(n^H)]$.

If, alternatively, the incumbent firm chooses $(\alpha, 1 - \alpha)$ his expected payoff is $[\alpha\pi_1^L(P^L) + (1 - \alpha)\pi_1^L(P^H)] + [\alpha\beta\pi_2^L(n^{PS}) + \alpha\delta\pi_2^L(n^L) + \alpha(1 - \beta - \delta)\pi_2^L(n^H) + (1 - \alpha)\pi_2^L(n^H)]$.

As $\pi_1^L(P^L) > \pi_1^L(P^H)$ and $\beta\pi_2^L(n^{PS}) + \delta\pi_2^L(n^L) + (1 - \beta - \delta)\pi_2^L(n^H) > \pi_2^L(n^H)$, the payoff from choosing P^L is greater than the payoff from choosing $(\alpha, 1 - \alpha)$. Notice that for any other price strategy (pure or mixed) the payoff is also lower than the one that results from choosing P^L , as for prices above P^L the incumbent firm is not maximizing profit and induces more entry, and for prices below P^L the firm is not maximizing the profit and induces the same entry.

Let us assume D^H . If the incumbent firm chooses the mixed strategy $(\alpha, 1 - \alpha)$, his expected payoff is

$$\begin{aligned} & [\alpha\pi_1^H(P^L) + (1 - \alpha)\pi_1^H(P^H)] \\ & + [\alpha\beta\pi_2^H(n^{PS}) + \alpha\delta\pi_2^H(n^L) \\ & + \alpha(1 - \beta - \delta)\pi_2^H(n^H) + (1 - \alpha)\pi_2^H(n^H)] \end{aligned} \quad (9)$$

or, equivalently, is

$\alpha[\pi_1^H(P^L) + \beta\pi_2^H(n^{PS}) + \delta\pi_2^H(n^L) + (1 - \beta - \delta)\pi_2^H(n^H)] + (1 - \alpha)[\pi_1^H(P^H) + \pi_2^H(n^H)]$. From this result we verify that the expected payoff from the mixed strategy is a linear combination between the “strategic payoff” (what the firm obtains if he sacrifices the profits in the first period and then, in the second period, has the change to compete with few rivals) and the “non-strategic payoff” (what the firm obtains if he maximizes period’s 1 profit and in the second period competes with $n^H - 1$ firms).

If, alternatively, the incumbent firm chooses P^L his expected payoff is

$$\pi_1^H(P^L) + [\beta\pi_2^H(n^{PS}) + \delta\pi_2^H(n^L) + (1 - \beta - \delta)\pi_2^H(n^H)]. \quad (10)$$

Comparing the payoffs from these two strategies we conclude that, for some parameters, for the incumbent firm the mixed strategy is better than the pure strategy P^L .

To get a deeper understanding of these results, we analyze some interesting values for the parameters of the regulator’s mixed strategy. We analyze the cases (i) $\delta = 0$ and $\beta = 1$; (ii) $\delta = 1 - \beta$; (iii) $\delta = 0$.

In these analysis we consider condition (1) $\pi_1^H(P^L) + \pi_2^H(n^P) \geq \pi_1^H(P^H) + \pi_2^H(n^H)$ (Remember that (1) is a necessary condition to have the pooling equilibrium.) and also, as $n^{PS} < n^P$, we know that $\pi_2^H(n^{PS}) > \pi_2^H(n^P)$. Then, we have

$$\begin{aligned} & \pi_1^H(P^L) + \pi_2^H(n^{PS}) \\ & > \pi_1^H(P^L) + \pi_2^H(n^P) \geq \pi_1^H(P^H) + \pi_2^H(n^H). \end{aligned} \quad (11)$$

Hence, $\pi_1^H(P^L) + \pi_2^H(n^{PS}) > \pi_1^H(P^H) + \pi_2^H(n^H)$. This is condition (2).

In case (i), $\delta = 0$ and $\beta = 1$, the regulator strategy is the pure strategy (n^{PS}, n^H) . This means that if the regulator

observes P^L she chooses n^{PS} for sure. Under condition (2), we conclude that the pure strategy P^L ensures a greater payoff for the incumbent firm than the mixed strategy $(\alpha, 1 - \alpha)$. Notice that $\alpha[\pi_1^H(P^L) + \pi_2^H(n^{PS})] + (1 - \alpha)[\pi_1^H(P^H) + \pi_2^H(n^H)] < \pi_1^H(P^L) + \pi_2^H(n^{PS})$. Therefore, in this particular case, the profile proposed is not a Perfect Bayesian Equilibrium.

In case (ii), $\delta = 1 - \beta$, the regulator strategy is $((\beta, 1 - \beta), 0)$, (n^H) . This means that, after observing P^L , the regulator chooses n^{PS} with probability β and n^L with probability $1 - \beta$. Choosing n^H after observing P^L is not a possibility. Under condition (2) we conclude that the pure strategy P^L ensures a greater payoff for the incumbent firm than the mixed strategy $(\alpha, 1 - \alpha)$. Notice that $\beta\pi_2^H(n^{PS}) + (1 - \beta)\pi_2^H(n^L) > \pi_2^H(n^{PS})$. Then, from condition (2), we have $\pi_1^H(P^L) + \beta\pi_2^H(n^{PS}) + (1 - \beta)\pi_2^H(n^L) > \pi_1^H(P^H) + \pi_2^H(n^H)$. Hence, the incumbent’s firm payoff with the pure strategy P^L is greater than the payoff from the mixed strategy:

$$\begin{aligned} & \pi_1^H(P^L) + \beta\pi_2^H(n^{PS}) + (1 - \beta)\pi_2^H(n^L) \\ & > \alpha[\pi_1^H(P^L) + \beta\pi_2^H(n^{PS}) + (1 - \beta)\pi_2^H(n^L)] \\ & + (1 - \alpha)[\pi_1^H(P^H) + \pi_2^H(n^H)]. \end{aligned} \quad (12)$$

Therefore, in this particular case, the profile described by Proposition 2 is not a Perfect Bayesian Equilibrium.

In case (iii), $\delta = 0$, the regulator strategy is $((\beta, 0, 1 - \beta), n^H)$. This means that, after observing P^L , the regulator chooses n^{PS} with probability β and n^H with probability $1 - \beta$. Choosing n^L after observing P^L is not a possibility. In this case we need to compare the incumbent payoff from mixed strategy, given by

$$\begin{aligned} & \alpha[\pi_1^H(P^L) + \beta\pi_2^H(n^{PS}) + (1 - \beta)\pi_2^H(n^H)] \\ & + (1 - \alpha)[\pi_1^H(P^H) + \pi_2^H(n^H)], \end{aligned} \quad (13)$$

with the one that results from the pure strategy P^L , given by $\pi_1^H(P^L) + \beta\pi_2^H(n^{PS}) + (1 - \beta)\pi_2^H(n^H)$. From this comparison we conclude that, for some parameters, the mixed strategy is a better response to the pure strategy P^L .

Overall, we conclude that, for some values of the parameters and when the choice of n^H after the observation of P^L has a positive probability in the regulator’s mixed strategy, the incumbent’s firm payoff from the mixed strategy $(\alpha, 1 - \alpha)$ is greater than the payoff from choosing alternative strategies (the pure strategy P^L , the pure strategy P^H , or others strategies). Then, in these cases, we have partial separating Perfect Bayesian Equilibrium. If, on the contrary, after observing P^L the regulator’s strategy does not contemplate the possibility of choosing n^H , there is not a partial separating equilibrium.

3.4. Interpretation of the Pooling Perfect Bayesian Equilibrium.

As the main objective of the paper is to analyze the impact of asymmetric information on entry regulation, we compare the final outcome of the pooling equilibrium $[(P^L, P^L), (n^P, n^H), (q = r, p = 0)]$ with the outcome that would be obtained if the regulator has information about demand. (We select the pooling equilibrium because the

results obtained in the partially separating equilibria go in the same direction from that of the pooling equilibria.)

In the definition of the number of firms that are allowed to enter the industry, the regulator only cares about the social welfare in the second period. However, as we said before, to evaluate the effects of the private information about demand on social welfare we need to consider both periods. This is because the incumbent firm's behavior in the first period depends on the regulatory policy, which has consequences on total welfare. Considering the pooling equilibria we conclude that the asymmetric information has an impact on social welfare. If demand is D^L there will be excessive entry, if demand is D^H there will be insufficient entry from a social point of view. However, when demand is D^H , the pooling equilibrium motivated by asymmetric information about demand does not have only negative consequences in spite of insufficient entry. The implementation of the limit price strategy has positive consequences in the short run (first period) resulting from the lower price. Hence, considering both periods, the final result is negative from a social point of view only if $W^H(P^L) + W^H(n^P) < W^H(P^H) + W^H(n^H)$.

In the description of the signalling game, we assume that the role of the regulator is to decide how many new firms could operate in the industry. We call this policy direct entry regulation. However, we can give a broader interpretation of the role of the regulator in the present game. We can consider that choosing n^j means that the regulator will take some actions to remove entry obstacles and to encourage the entry of n^j new firms. These actions will be more intensive if j is high. Then, we can interpret the results of the signalling game in the context of indirect entry regulation, which we define as the regulator's decisions that influence the number of firms in the industry. (This is the perspective adopted, for example, by De Fraja [12] in the study of the impact of regulation on entry.) With this interpretation we conclude that, in the pooling equilibrium described, the incumbent firm has the incentive to induce the regulator not to develop too intensive actions in the promotion of entry.

We can illustrate this interpretation with an example from the European airline industry. In the late 1990s, several alliances and mergers between airline companies occurred in Europe. According to European legislation when mergers have economic consequences at the European level they have to be authorized by the European Commission. Furthermore, when the companies involved in the mergers have a significant number of overlapping routes, the European Commission makes a detailed analysis of the impact on competition. However, the European Commission only considers the hypothesis of adopting an active role in the merger process if the market demand is of significant size. (For example, in the evaluation of the competition features in the Lufthansa/SAS process, the European Commission only considered routes with capacity exceeding 30,000 seats per year (Stragier, [13]).) If the market demand is perceived as narrow, the European Commission does not take actions to encourage new entry, even if the merger creates a monopoly.

When demand size is significant and the merger can have important benefits (an increase in efficiency, in particular), the European Commission's past approach has been to

authorize the merger while, at the same time, imposing several obligations on the incumbent firms in order to promote entry. These obligations can be, for example, to make available some landing and take-off slots at congested airports, to reduce the frequency of some flights, to enter into interlining arrangements with the entrants, to open the frequent flyer programmes to the entrants' customers. (For a detailed description of the European Commission policy for airline mergers see Stragier [13].) According to our model, if the incumbent firms can convince the Commission that demand is narrow, the intensity of the obligations designed to promote entry might be weak, and then entry is less likely.

The asymmetric information between the firms and the regulator plays a central role in the described process. Firms have a deeper knowledge of the market characteristics and can manipulate many variables, including the price, as in the signal model presented above. In the airline industry, firms can also use the network definition as a powerful variable to manipulate the size of the demand perceived by outside entities. The substitution between direct and indirect flights (the ones with one or more stopovers) has a strong impact on the perceived demand size of each route. (In the United States there is empirical evidence of this type of incumbent firms' strategy, under which the incumbent firms use the route definition as an instrument variable to deter entry (Transportation Research Board, [14]).)

3.5. Illustration of the Model. In order to illustrate the results of the signalling game we present a particular case and we identify the parameter space under which the pooling equilibrium occurs. We assume a linear and stationary demand given by $Q = \theta - P$, no variable costs and only one potential entrant. The parameter θ can have two values, θ^L or θ^H , with $\theta^L < \theta^H$, representing low or high demand, respectively. F represents the fixed cost per period borne by each firm that operates in the market. We assume that the regulator knows the demand function $Q = \theta - P$, but it does not know the value of θ .

Considering that \tilde{P} represents the optimal price for the duopoly case of the second period when demand is low, we must set an upper bound for the fixed cost F . This guarantees that entry is not blocked by the level of F . However, if the fixed cost is too small the regulator would prefer to allow entry for every demand size. In the regulator's perspective, if F is too small, the benefits of the duopoly (resulting from the price decrease) overtake the damage resulting from the cost duplication. Then, \tilde{P} must be greater than $\sqrt{(\theta^L)^2 - 8F/2}$. (See Appendix B for detail explanations of the results for the particular case of the signalling model.) Therefore, the application of the signalling model for linear demand is relevant for every duopoly behavior in the second period as long the duopoly price satisfy this condition.

Cournot competition is an example of the duopoly behavior described above. Applying Proposition 1 to the case of Cournot competition in the second period we conclude that $[(\theta^L/2, \theta^L/2), (n = 0, n = 1), (q = r, p = 0)]$ is a Pooling Perfect Bayesian Equilibrium if $r(\theta^L)^2 + (1 - r)(\theta^H)^2 \leq (72/5)F$ and $r((\theta^H)^2/9) \leq (\theta^L/2)(\theta^H - \theta^L/2)$.

When the duopoly competition in the second period is quite intense and leads to a duopoly price below the critical level $\sqrt{(\theta^L)^2 - 8F/2}$, the regulator's problem about entry authorization ceases to exist. This happens because the positive effect on social welfare of the price reduction overtakes the negative consequence of the cost duplication, and even if demand is low, the regulator prefers to allow entry. Stackelberg competition illustrates this case.

We conclude that the application of the signalling model when the demand has a linear specification requires a moderate degree of postentry competition.

4. Conclusions

From the signalling model presented, we show that the choice of a low price by the incumbent firm is part of an equilibrium strategy of a pooling and a partially separating Perfect Bayesian Equilibria. At these equilibria, the regulator authorizes the entry of a small number of new firms, whether demand size is low or high. This decision benefits the incumbent firm.

The existence of the equilibria requires that the incumbent firm must highly value the fact of sharing the market with few firms.

The overall effect on social welfare of the price strategy described depends on the tradeoff between short-run benefits (resulting from lower price in the first period) and long-run losses (resulting from weaker competition in the second period).

In order to study the impact of the type of competition after entry on the equilibrium strategies, we consider a particular case of the model. We assume linear demand, variable costs normalized to zero, and only one entrant. We conclude for the existence of the Pooling Perfect Bayesian Equilibrium described in the general model, as long as the duopoly interaction expected for the second period leads to a price above a critical level. Cournot competition is an example of this case.

Appendices

A. The Pooling Equilibrium

$[(P^1, P^1), (n^P, n^H), (q = r, p = 0)]$ with $P^1 < P^L$

(1) If (P^1, P^1) is an equilibrium strategy for the incumbent firm, then the regulator information set corresponding to P^1 is on the equilibrium path. Hence, the regulator's belief is updated by Bayes' rule and the incumbent firm's strategy. Therefore, $q = r$, the prior belief. Given this belief, the regulator's best response following P^1 is to choose n^P , as this is the value of n that maximizes welfare.

(2) To determine whether the incumbent firm is willing to choose P^1 for both demand sizes we need to compare the payoffs from choosing P^1 with the payoffs from choosing the alternative price to P^1 . As P^1 is lower than P^L , the alternative to P^1 is not equal under D^L or D^H . If demand type is D^L , the

best alternative to P^1 is P^L , while if demand type is D^H , the best alternative to P^1 is P^H .

If the regulator's response to $P > P^1$ is n^P , the incumbent firm's payoff is $\pi_1^L(P > P^1) + \pi_2^L(n^P)$ when demand type is D^L , which is greater than the payoff with P^1 , $\pi_1^L(P^1) + \pi_2^L(n^P)$. If, on the contrary, demand type is D^H , the payoff is $\pi_1^H(P > P^1) + \pi_2^H(n^P)$, which is greater than the payoff with P^1 , $\pi_1^H(P^1) + \pi_2^H(n^P)$. Then, if (P^1, P^1) belongs to an equilibrium, the regulator response to $P > P^1$ cannot be n^P .

If the regulator's response to $P > P^1$ is n^H , the incumbent firm's payoff is $\pi_1^L(P > P^1) + \pi_2^L(n^H)$ when demand type is D^L or is $\pi_1^H(P > P^1) + \pi_2^H(n^H)$ when demand type is D^H . From the comparison of these payoffs with the corresponding payoffs when the incumbent firm chooses P^1 , we conclude that the incumbent firm does not choose $P > P^1$ for D^L or D^H when the regulator response to $P > P^1$ is n^H , as long as the following conditions are met $\pi_1^L(P > P^1) + \pi_2^L(n^H) < \pi_1^L(P^1) + \pi_2^L(n^P)$ and $\pi_1^H(P > P^1) + \pi_2^H(n^H) < \pi_1^H(P^1) + \pi_2^H(n^P)$.

Therefore, to have an equilibrium with (P^1, P^1) , it is necessary to impose an attractive limit price strategy for the incumbent firm both when D^L and D^H .

(3) Choosing n^H is the best regulator's response to $P > P^1$ if $pW^L(n^H) + (1-p)W^H(n^H) > pW^L(n^P) + (1-p)W^H(n^P)$ which is true for $p = 0$.

B. The Pooling Equilibrium with Linear Demand, no Variable Costs, and One Entrant

For the first period we use the following standard results: (a) Monopoly with profit maximization: $= \theta/2$; $P = \theta/2$; $\pi = \theta^2/4 - F$ and $W = (3/8)\theta^2 - F$; (b) Monopoly without profit maximization: $\pi = P(\theta - P) - F$ and $W = (\theta - P)^2/2 + P(\theta - P) - F$.

Considering that \tilde{P} and \tilde{q}_i (with $i = 1, 2$) represent, respectively, the optimal price and optimal individual quantities for the duopoly case, we must ensure that $W^L(n = 0) > W^L(n = 1) \Rightarrow 3/8(\theta^L)^2 - F > (\theta^L - \tilde{P})^2/2 + \tilde{q}_1\tilde{P} - F + \tilde{q}_2\tilde{P} - F$ and $\pi_2 > 0 \Rightarrow \tilde{q}_2\tilde{P} - F > 0$, respectively.

To Cournot competition we use the following standard results: $q_1 = q_2 = \theta/3$; $P = \theta/3$; $Q = (2/3)\theta$; $\pi = \theta^2/9 - F$; $W = (4/9)\theta^2 - 2F$. For this case, we have $(5/72)(\theta^L)^2 < F < (5/72)(\theta^H)^2$ and $F < (\theta^L)^2/9$, respectively. Then, the entrant is always willing to enter the market the regulator's problem resulting from its lack of information about demand size exists. Notice that if F is outside that range defined above, the regulator does not face any dilemma as long as the fixed cost is known (as we assume). If F is too large ($F > (5/72)(\theta^H)^2$), social welfare is higher with monopoly even when demand is D^H , because of cost duplication resulting from entry. If F is too low ($F < (5/72)(\theta^L)^2$), social welfare is higher with two firms than with monopoly even when demand is D^L , because the positive effect of the price decrease overtakes the negative consequence of cost duplication. Notice that for low demand and if entry occurred, the second period's price would be $\tilde{P} = \theta^L/3$. This price is above the critical level $\sqrt{(\theta^L)^2 - 8F/2}$.

The standard results for Stackelberg competition with two firms are $q_2 = (\theta - q_1)/2$ is the best reply function of

firm 2; $q_1 = \theta/2$; $q_2 = \theta/4$; $P = \theta/4$; $\pi_1 = \theta^2/8 - F$; $\pi_2 = \theta^2/16 - F$; $W = (15/32)\theta^2 - 2F$. To guarantee that entry is not blocked for both demand types, it is necessary to assume that $F < (\theta^L)^2/16 - 2F$. However, for this values of F the regulator is always willing to authorize the entry. Then, the regulator does not face any dilemma regarding its decision even without knowing the demand size. Therefore, in this case, the signalling game described in the previous section is not relevant. We can immediately reach this conclusion by observing that the optimal Stackelberg price when demand is low $\theta^L/4$ is below the critical value $\sqrt{(\theta^L)^2 - 8F/2}$ for $F < (\theta^L)^2/16$.

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References

- [1] N. G. Mankiw and M. D. Whinston, "Free entry and social inefficiency," *The Rand Journal of Economics*, vol. 17, no. 1, pp. 48–58, 1997.
- [2] D. M. Newbery, *Restructuring and Regulation of Network Utilities*, MIT Press, Cambridge, Mass, USA, 2000.
- [3] T. R. Lewis and D. E. M. Sappington, "Regulating a monopolist with unknown demand," *The American Economic Review*, vol. 78, no. 5, pp. 986–998, 1988.
- [4] P. Milgrom and J. Roberts, "Limit pricing and entry under incomplete information: an equilibrium analysis," *Econometrica*, vol. 50, no. 2, pp. 443–459, 1982.
- [5] Drew Fudenberg and Jean Tirole, "A "Signal-Jamming" theory of predation," *The Rand Journal of Economics*, vol. 17, no. 3, pp. 366–376, 1986.
- [6] J. Kim, "Signaling rather than incentive mechanism for entry regulation," Discussion Paper Series A 403, Institute of Economic Research, Hitotsubashi University, 2001.
- [7] C. C. von Weizsäcker, "A welfare analysis of barriers to entry," *Bell Journal of Economics*, vol. 11, no. 2, pp. 399–420, 1980.
- [8] M. K. Perry, "Scale economics, imperfect competition and public policy," *Journal of Industrial Economics*, vol. 32, no. 3, pp. 313–333, 1984.
- [9] K. Suzumura and K. Kiyono, "Entry barriers and economic welfare," *The Review of Economic Studies*, vol. 54, no. 1, pp. 157–167, 1987.
- [10] M. H. Riordan, "Imperfect information and dynamic conjectural variations," *The Rand Journal of Economics*, vol. 16, no. 1, pp. 41–50, 1985.
- [11] E. Rasmusen, *Games and Information: An Introduction to Game Theory*, Blackwell, Oxford, UK, 2001.
- [12] G. De Fraja, "Pricing and entry in regulated industries: the role of regulatory design," *Journal of Public Economics*, vol. 64, no. 2, pp. 259–278, 1997.
- [13] J. Stragier, "Airline alliances and mergers: the emerging commission policy," in *Proceedings of the 13th Annual Conference of the European Air Law Association*, Zurich, Switzerland, November 2001.
- [14] Transportation Research Board, "Entry and competition in the us airline industry: issues and opportunities," Special Report 255, National Academy of Science US, 1999.



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