Hitotsubashi Journal of Economics 53 (2012), pp.71-84.

SHOULD REGULATORS BE MORE PROACTIVE ABOUT ENTRY? AN EVALUATION UNDER ASYMMETRIC INFORMATION*

PAULA SARMENTO

CEF.UP and Faculty of Economics, University of Porto
Porto 4200–464, Portugal
sarmento@fep.up.pt

AND

ANTÓNIO BRANDÃO

CEF.UP and Faculty of Economics, University of Porto
Porto 4200–464, Portugal
abrandao@fep.up.pt

Received October 2011; Accepted February 2012

Abstract

We compare the costs of two regulatory policies about the entry of new firms. We consider an incumbent firm that has more information about the market demand than the regulator and can use this advantage to persuade the regulator to make entry more difficult. With the first regulatory policy the regulator uses the incumbent price pre-regulation to get information about the demand. With the second regulatory policy the regulator designs a mechanism to motivate the incumbent firm to price truthfully. We conclude that for a wide range of situations, social welfare is strictly higher with the more active regulatory policy.

JEL Classification: C73, D82, L13, L51
Keywords: entry regulation, signaling, mechanism design

I. *Introduction*

To enter the markets can be a difficult process for firms due both to institutional and economic reasons. Entry regulation is one of these reasons. In many countries there are many

* We are very grateful to Steffen Hoernig and to the participants on the 1st *Workshop on the Economics of ICTs* (March 2010), Porto. Their comments significantly improved the paper. Any remaining shortcomings are, of course, our own responsibility.

administrative and bureaucratic requirements that make entry a long and difficult process. Sometimes the governments fix the number of entrants. This is what we call direct entry regulation. Additionally incumbent firms can strategically create impediments and difficulties for potential entrants in order to protect their markets. In this paper we analyze the costs of entry regulation resulting from the strategic behavior of the incumbent firms that use their superior knowledge to persuade the regulator to make entry more difficult or to prevent entry.

Asymmetric information is considered by both the literature and by the regulatory authorities as an essential feature that must be taken into consideration to design regulatory policy. Regulated firms have more information about themselves and about the market than does the regulator. This informational advantage can be strategically exploited by the incumbent firms to avoid greater competition in the market. As in many cases the authorities have a direct or indirect influence on the number of firms that can enter the market, the incumbent firm can use his knowledge about the market to persuade the regulator to prevent the entry of some new firms, for instance, maintaining the level of entry barriers. One of the market characteristics that generally the incumbent firm knows better than the regulator is market demand. Firms have superior knowledge of the quality of the products and of the expected reaction of the consumers to that quality and they have closer and more frequent contact with their customers than does the regulator (Lewis and Sappington, 1988).

One way in which the regulator can get information about the demand size is by observing the price fixed by the incumbent firm. Although the regulator has other resources that she can use to measure the demand size, the price fixed by the incumbent firm is an important piece of information. Therefore, the incumbent firm can fix the price in order to mask the true size of demand in the spirit of the Milgrom and Roberts (1982) signaling model. Differently from the Milgrom and Roberts framework we consider that the incumbent firm tries to prevent entry using regulator policy instead of the expectations of the entrant. Kim (2010) also analyzes the relationship between entry regulation and strategic behavior of incumbent firms in a framework of asymmetric information. Kim (2010) reaches the unexpected result that entry regulation can perform better under incomplete information than under complete information due to the positive effects on welfare of the incumbent firm' strategic behavior. Our analysis departs from Kim (2010) in two ways. Firstly, we consider the existence of many potential entrants, while Kim (2010) considers only one potential entrant. Consequently, in our framework the regulator's decision is about the number of new firms that should be authorized to enter instead of being a dichotomic decision (authorize entry versus not to authorize entry) as in Kim (2010). Secondly, we consider asymmetric information about demand size and not about incumbent's costs as demand size is a crucial feature to the regulatory decision about the number of firms that optimally should be in the market. We show that considering many potential entrants and asymmetric information about demand significantly changes the conclusions regarding the efficiency of entry regulation. We prove that the strategic behavior of the incumbent firm can decrease social welfare when there is entry regulation and asymmetric information.

Moreover, we investigate if the regulator that seeks welfare maximization would benefit from having more initiative in the relation with the incumbent firm. Even if the regulator lacks information about the demand size she can design a mechanism that motivates the incumbent firm to price truthfully. Is it a better solution? The problem is that this mechanism results in additional costs to the regulator in order to motivate the incumbent to reveal the truth. Our main concern is to understand if more initiative by the regulator is rewarding compared to the equilibria of the signaling game. This is an important issue to understand the best behavior of the regulator in situations where some kind of entry regulation is necessary.

In many industries entry regulation is not as frequent as it was in the past. 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 (Stragier, 2001). Nevertheless, we can advance several arguments, either theoretical or resulting from empirical observation, that support the importance of entry regulation. In some industries 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 Winston (1986) and Suzumura and Kiyono (1987) to oligopoly markets. Furthermore, in industries with partial liberalization often entry is gradual and controlled. This happened, for instance, in mobile telecommunications where, due to the scarcity of a vital input, the radio spectrum, new firms needed the regulator's approval to enter. Before conceding licenses, regulators defined the number of firms that could 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 (Newbery, 2000, p.323).

Also, we can give a broader interpretation of entry regulation and consider that it means the public authority's actions that make entry easier or more attractive. In this context the public authority's decision is about the administrative and bureaucratic procedures that must be accomplished to enter the market or about the intensity of the entry promotion policy, as happens, for example, in the definition of the remedies that accompany merger authorizations. Then, the motivation for entry regulation is the promotion of entry.

The structure of the paper is the following: section II describes the framework used to discuss the cost of the regulatory policies. Section II.1 describes the model with symmetric information, then, section II.2 analyses the regulatory policies under asymmetric information. Two hypotheses are considered: with the first regulatory policy, the regulator defines the number of entrants after observing the price fixed by the incumbent firm. With the second regulatory policy, the regulator gives information about how it will decide the maximum number of entrants before the observation of the incumbent's price. These different regulatory policies are model with a signaling game for the first case (section II.2. (1)) and with a mechanism design game for the second case (section II.2. (2)). Section II.3 compares the two regulatory policies regarding their regulatory costs and finally section III presents the main conclusions.

II. *The Model*

We consider a monopoly market with many potential entrants. All firms have identical cost functions equal to a positive constant F and firms' variable costs are normalized to zero. The demand is represented by a linear function equal to $P=1-Q$ (low demand or D^L) or to

$P=a-Q$ with $a>1$ (high demand or D^H).

Our analysis considers two periods with price decisions: firstly the monopolist decides the price and obtains profits; secondly the regulator decides about entry and afterwards a new price is set by oligopolistic interaction.

Regarding the objective functions of the participants we consider that the incumbent firm maximizes the sum of his profits in the two periods (we ignore discounting) and the regulator maximizes social welfare (defined as the sum of consumer surplus and firms' profits) in the second period.[1] Here the entrants do not have a strategic role, since we assume that there is a large number of new firms that wish to enter the market.

1. The Model with Complete Information

First we characterize the market results under complete information in order to establish a benchmark. In this case all the market participants (incumbent firm, entrants and regulator) know if demand is low or high. Then, the sequence of decisions is the following: at stage 0 Nature chooses the demand size, D^L or D^H with probability r and $1-r$, respectively. At stage 1 all the participants observe the demand size. At stage 2 the incumbent firm chooses the price that maximizes his profit and obtains the corresponding profits. The optimal monopoly price is represented by p_1^L or p_1^H when demand is D^L or D^H, respectively. At stage 3 there are many firms that want to enter in the market regardless of demand size. The number of firms that maximizes social welfare is represented by n^L or n^H when D^L or D^H, respectively. Therefore, the regulator authorizes n^L-1 or n^H-1 new firms. At stage 4 the oligopolistic interaction sets another price and the corresponding profits.

The game is solved by backward induction. Considering Cournot competition among n firms at stage 4, the equilibrium prices ($p_2^L(n)$ and $p_2^H(n)$) and the corresponding individual profits ($\pi_2^L(n)$ and $\pi_2^H(n)$) for low and high demand are the following:

$$p_2^L(n)=\frac{1}{1+n} \qquad \text{and} \qquad \pi_2^L(n)=\frac{1}{(1+n)^2}-F$$

$$p_2^H(n)=\frac{a}{1+n} \qquad \text{and} \qquad \pi_2^H(n)=\frac{a^2}{(1+n)^2}-F$$

At stage 3 the regulator decides the number of new firms in order to maximize social welfare. The social welfare functions are given by:

$$W^L(n)=\frac{n^2}{2(1+n)^2}+\frac{n}{(1+n)^2}-nF \qquad \text{and} \qquad W^H(n)=\frac{a^2n^2}{2(1+n)^2}+\frac{a^2n}{(1+n)^2}-nF$$

The numbers of firms that maximize social welfare are $n^L=\sqrt[3]{\frac{1}{F}}-1$ and $n^H=\sqrt[3]{\frac{a^2}{F}}-1$ for low and high demand, respectively.

At stage 2 prices and monopolist profits at the profit maximization solution are given by:

$$p_1^L=\frac{1}{2} \qquad \pi_1^L(p_1^L)=\frac{1}{4}-F$$

[1] Notice that the regulator's decision about entry is taken at the beginning of the second period.

$$p_1^H = \frac{a}{2} \qquad \pi_1^H(p_1^H) = \frac{a^2}{4} - F$$

It is important to notice that the regulatory problem is only relevant when the regulator's optimal decision depends on the demand size. Otherwise, the asymmetric information does not create any regulatory problem. Analyzing the optimal number of firms (n^L and n^H) we conclude the following:

i) When demand is D^L the regulator prefers not to authorize any new firm when $F \geq 0.125$. For $F = 0.125$ the optimal number of firms (n^L) is 1 (monopoly structure). For $F < 0.125$ the regulator prefers entry until the total number of firms reaches n^L.

ii) When demand is D^H the regulator prefers not to authorize any new firm when $F \geq 0.125a^2$. For $F = 0.125a^2$ the optimal number of firms (n^H) is 1 (monopoly structure). For $F < 0.125a^2$ the regulator prefers to authorize $n^H - 1$ firms

Therefore, when $F \geq 0.125a^2$ the regulator prefers not to authorize any new firm whatever the demand size (as $a > 1$ by assumption). When $F < 0.125a^2$ the optimal regulator's decision depends on the demand size. Notice that when $F < 0.125$ the regulator prefers to authorize entry both when D^L or D^H, but the optimal number of firms is different in each case.

Additionally, to have an excess entry problem it is necessary that the number of firms that wish to enter is higher than the number of new firms that maximize social welfare. The numbers of firms that wish to enter in the market are $n^{Lfree} = \sqrt{\frac{1}{F}} - 1$ and $n^{Hfree} = \sqrt{\frac{a^2}{F}} - 1$ for low and high demand respectively, which are higher than $n^L - 1$ and $n^H - 1$, respectively. Then, we concentrate our study on this interval, as it is synthesized by the following assumption.

Assumption: Assume $F < 0.125a^2$.

2. The Model with Asymmetric Information

Now we consider what happens when the regulator has less information than the incumbent firm regarding demand size. To analyze the effects of asymmetric information we study two scenarios that represent two different regulatory policies. Under the first regulatory policy, the regulator sets the maximum number of entrants after observing the price defined by the incumbent firm. This regulatory policy is studied with a signaling game, where the regulator considers the incumbent's price as a signal about demand size.

The second regulatory policy demands a more active attitude from the regulator. Before the price setting by the incumbent firm, the regulator directly asks the incumbent firm which is the demand size and, at the same time, informs him about how many firms can enter in the market depending on the incumbent's firm answer. Then, after the definition of the incumbent's price, the regulator sets the number of new firms, implementing the announced policy. This regulatory policy is approached with a mechanism design and it corresponds to the application of the Revelation Principle.[2]

[2] Myerson (1979) was one of the founders of the Revelation Principle. For more details on this principle see, for instance, Laffont and Tirole (1993).

(1) The signaling model

The timing of the signaling game is the following: initially Nature chooses the demand size, D^L or D^H with probability r and $1-r$, respectively. Afterwards, only firms observe Nature's choice. At stage 2 the incumbent firm chooses the price and obtains the corresponding profits. At stage 3 the regulator observes the incumbent's price and updates her beliefs about demand size. Then, the regulator decides the maximum number of entrants. At stage 4 the oligopolistic interaction between firms leads to the establishment of another price and of corresponding profits.

We characterize both separating and pooling equilibria of the signaling game. As usual in this type of games there are multiple equilibria. We narrow our analysis to the equilibria that pass the Intuitive Criterion by Cho and Kreps (1987).

In the description of the signaling model we assume the following notation. The strategies are represented by a pair of values: for the incumbent firm (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 (n^w, n^z) means that she 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. The regulator's updated beliefs are represented by the probability of each demand size conditional on the observed price and are represented by $\mathrm{Prob}(D^L \backslash p)$ and $\mathrm{Prob}(D^H \backslash p)$. Also, $\pi_1^i(p)$ represents the monopolist profit in the first period when demand is D^i and price is p with i=L or H.

Separating equilibria

The separating equilibria results from the incumbent firm's incentive to set a low price when demand is D^L in order to signal that demand is low, distinguishing from the high demand scenario. This low price (that must be lower than p_1^L) has to be sufficiently low so that, if demand is D^H, the incumbent firm has no incentive to choose it. Then, the incumbent firm follows different price strategies depending on demand size. Proposition 1 summarizes the separating equilibrium.

Proposition 1: There exists a unique separating Perfect Bayesian Equilibrium (PBE) that passes the Intuitive Criterion by Cho and Kreps as follows:
$[(\bar{p}, p_1^H);\ (n^L,\ n^H);\ \mathrm{Prob}(D^L \backslash p)=1 \text{ if } p \in [0,\ \bar{p}],\ \mathrm{Prob}(D^L \backslash p)=0 \text{ if } p \in (\bar{p},\ \infty)]$, with $\bar{p}=a\left(\frac{1}{2}-\frac{1}{2}\sqrt{4x+1}\right)$ and $x=\frac{1}{\left(\sqrt[3]{\frac{1}{F}}\right)^2}-\frac{1}{\left(\sqrt[3]{\frac{a^2}{F}}\right)^2}-\frac{1}{4}$.

Proof: See Appendix A.

Proposition 1 is parallel to the Proposition 1 of Kim (2010), with the main difference being the assumption of asymmetric information about demand size. Additionally, and as stated before, we assume the existence of many potential entrants instead of only one entrant. However, regarding the separating equilibrium, the most relevant difference from Kim's (2010) model is the nature of the asymmetric information because if we assumed only one potential entrant we would obtain the same result as in Proposition 1.[3] The important point from Proposition 1 is that, as in Kim (2010), the authorized number of new firms at the separating equilibrium is equal to the one that would be obtained with complete information.

Pooling equilibria

The pooling equilibria results from the incumbent's firm incentive with high demand to set a price equal to the one he sets if demand is low. With this strategy the regulator cannot extract any additional information about demand size from the observation of the incumbent firm's price. The pooling PBE are described by Proposition 2.

Proposition 2: The strategies and beliefs represented by $[(p^p, p^p), (n^p, n^H)$, Prob $(D^L \mid p)=r$ if $p\in[0, p^p]$ and Prob $(D^L \mid p)=0$ if $p\in(p^p, \infty)]$ with $p^p\in[\bar{p}, p_1^L]$ and $n^p=(\frac{r+a^2-a^2r}{F})^{\frac{1}{3}}-1$ are PBE that pass the Intuitive Criterion by Cho and Kreps.

Proof: See Appendix B.

The pooling PBE have the following intuitive description. Whatever the demand size, the incumbent firm chooses the same price p^p (equal or lower than p_1^L). The purpose 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^p becomes r and the probability of low demand if the observed price is higher than p^p becomes *0*. Then, the regulator allows the entry of n^p-1 firms if the price is p^p, or n^H-1 firms if the price is higher than p^p. Notice that n^p is an intermediate value between n^L and n^H, decreasing with r. This means that n^P is closer to n^L when the probability of low demand is high.

At the pooling equilibria the incumbent firm strategically uses the entry regulation and the private information about demand to induce the regulator to protect its market from competition.

It is important to note that the regulatory problem described is relevant only if the social welfare number of firms (n^p) is lower than the free entry number of firms for the low demand case (n^{Hfree}). Otherwise, the regulatory decision of setting the maximum number of firms at n^p would have no effects, as only $n^{Lfree}-1$ firms would be willing to enter in the market. Comparing n^p with n^{Lfree}, we conclude that the regulatory problem is relevant for all possible values of r.

Furthermore it is important to highlight that the result of Proposition 2 departs significantly from Kim's (2010) conclusions about the pooling equilibria. Kim (2010) finds that pooling equilibria do not exist when the prior probability of the low type is lower than a critical level. This is explained by the fact the if the probability of the low type is very low the regulator will always authorize entry for any state of Nature and therefore each type of incumbent firm will

[3] We acknowledge an anonymous referee for pointing out to us this property.

choose the price that maximizes the period's 1 profit. However, this result strictly depends on the fact that the regulator's strategy is dichotomic. When we depart from this strategy and we consider that the regulator has to decide the number of new firms then we do not have a constraint on the existence of pooling equilibria. This happens because a low probability of low demand will have as consequence the authorization of a high number of new firms as n^p is decreasing with r. It is worthwhile to emphasize that here the differences from Kim's (2010) conclusions crucially depend on the assumption of many potential entrants. If in our model we assumed only one potential entrant we would find that the pooling equilibria only exist for some values of the prior probabilities as in Kim (2010).[4]

(2) Mechanism design model

The mechanism design model represents the regulatory policy with more initiative by the regulator. With this policy the regulator gives information about how she will decide the maximum number of entrants dependent on the incumbent's answer to a direct question from the regulator about demand size. The regulator's purpose with this policy is to induce the incumbent firm to truthfully reveal demand size. The information given by the regulator about how she will decide the maximum number of entrants is represented by the following contract: the regulator authorizes n_1-1 entrants if the incumbent's answer is "low" and authorizes n_2-1 entrants if the incumbent's answer is "high", with $n_2>n_1$. This contract (that is, n_1 and n_2 values) must be set such that the incumbent firm has the incentive to truthfully reveal the demand size.

The mechanism design is described as a game with the following timing: at stage 0 Nature chooses the demand size D^L or D^H, with probability r and $1-r$, respectively. At stage 1 firms observe Nature's choice. At stage 2 the regulator announces the regulatory policy about entry. At stage 3 the incumbent firm chooses the price and obtains the corresponding profits. At stage 4 the regulator applies the regulatory policy deciding how many new firms can enter the market. At stage 5 the oligopolistic interaction between the firms leads to the establishment of another price and of the corresponding profits.

The regulator sets n_1 and n_2 in order to maximize the expected value of the social welfare, $E[W(n)]=rW^L(n_1)+(1-r)W^H(n_2)$, and ensuring that the incumbent has the incentive to reveal the true demand size. This incentive is represented by the following incentive compatibility conditions:

$$\text{i) } \pi_1^L(p_1^L)+\pi_2^L(n_1)\geq\pi_1^L(p_1^H)+\pi_2^L(n_2)$$

$$\text{ii) } \pi_1^H(p_1^H)+\pi_2^H(n_2)\geq\pi_1^H(p_1^L)+\pi_2^H(n_1)$$

As $n_2>n_1$, if demand is D^L the incumbent firm maximizes his profit answering "low" and choosing p_1^L. In this way, the regulator authorizes the entry of a few firms. Then, the first condition always holds. On the contrary, if demand is D^H, the incumbent firm only answers "high" if $\pi_1^H(p_1^H)+\pi_2^H(n_2)\geq\pi_1^H(p_1^L)+\pi_2^H(n_1)$. We assume a perfect coherence between the incumbent's price choice and his answer to the regulator's question about demand size. Hence, if the incumbent's answer is "low" he chooses the optimal price to low demand size (p_1^L).

Therefore, the regulator's problem can be written as:

---

[4] For detailed proof of this result see Appendix C.

$$\text{Maximize } rW^L(n_1)+(1-r)W^H(n_2)$$
$$\text{s.t. } \pi_1^H(p_1^H)+\pi_2^H(n_2)\geq\pi_1^H(p_1^L)+\pi_2^H(n_1)$$

In the maximization problem we do not consider the participation constraints (as is usual in this type of problems) because we assume that the incumbent cannot refuse entry regulation and the entrants always wish to enter in the market.

Solving the problem we find that $n_1=\sqrt[3]{\frac{1}{F}+\frac{2a^2\lambda}{Fr}}-1$ and $n_2=\sqrt[3]{\frac{a^2}{F}-\frac{2a^2\lambda}{F(1-r)}}-1$, where λ is the Lagrange multiplier. The regulator decides simultaneously the values of n_1, n_2 and λ.

Notice that n_1 and n_2 are between n^L and n^H. For $\lambda=0$, we obtain the symmetric information solution, as n_1 and n_2 are equal to n^L and n^H, respectively. When λ increases n_1 and n_2 approach each other, increasing their difference to n^L and to n^H, respectively. From this analysis we can compute an upper limit to λ (the value such that $n_1 = n_2$, $\lambda^{\max}=\frac{r(1-r)(a^2-1)}{2a^2}$)[5]. For $\lambda^{\max}$ we find that $n_1=n_2=n_p$, that is, we have the same result as with the pooling equilibria of the signaling model.

Similar to the signaling problem, here it is also necessary to ensure that n_1 is lower than the free entry number of firms for the low demand case. Otherwise, the regulatory decision of authorizing the maximum of n_1-1 new firms would have no effects, as only $n^{Lfree}-1$ firms would be willing to enter in the market. Comparing n_1 with n^{Lfree} we conclude that the mechanism design problem is relevant as long as $\lambda<(\frac{1}{\sqrt{F}}-1)\frac{r}{2a^2}$.

3. Comparison of the Regulatory Policies

To compare the entry regulatory policies we compute the welfare cost of each policy taking as a reference the complete information outcome. We consider that the social welfare cost of entry regulation results from the authorization of a different number of new firms when the incumbent firm has an informational advantage. As we mentioned above and was proven by Kim (2010)[6], the separating equilibrium of the signaling game generates the same number of authorized firms as the complete information. Therefore, at the separating equilibrium there is no social welfare cost. The cost at the pooling equilibria and at mechanism design equilibrium results from the authorization of a higher number of firms than the social optimal when demand is low (n^p in the pooling equilibria or n_1 in the mechanism design, instead of n^L) and a lower number of new firms than the social optimal when demand is high (n^p in the pooling equilibria or n_2 in the mechanism design, instead of n^H). Notice that it is possible to infer the social welfare costs from the comparison of the number of firms because both social welfare functions ($W^L(n)$ and $W^H(n)$) are monotonically decreasing in n to the right of their maximum value, n^L or n^H, respectively.

When defining the welfare cost of each regulatory policy, and due to tractability reasons,

---

[5] Notice that with $\lambda>\lambda^{\max}$, $n_2<n_1$ which is not relevant from an economic point of view.

[6] See the proof of Proposition 4 of Kim (2010).

we consider the following variable transformations regarding the relevant number of firms:

$$(n^L+1)^3=\frac{1}{F}=N^L \qquad (n^H+1)^3=\frac{a^2}{F}=N^H$$

$$(n^p+1)^3=\frac{1}{F}(r+a^2-a^2r)=\mathrm{N}^{\mathrm{p}}$$

$$(n_1+1)^3=\frac{1}{F}+\frac{2a^2\lambda}{Fr}=N_1 \qquad (n_2+1)^3=\frac{a^2}{F}-\frac{2a^2\lambda}{F(1-r)}=N_2$$

Then, the expected cost at the pooling equilibria is given by: $r(N^p-N^L)+(1-r)(N^H-N^p)=\frac{2r}{F}(r+a^2-a^2r-1)$. And the expected cost at the mechanism design equilibrium is given by: $r(N_1-N^L)+(1-r)(N^H-N_2)=\frac{4a^2\lambda}{F}$.

As foreseeable, in the mechanism design case the expected cost of the regulatory policy is increasing with λ (the Lagrange multiplier). For high values of λ, the regulator is giving the incumbent firm a large incentive to answer truthfully. This incentive is the authorization of a smaller number of new firms, n_2-1 instead of n^H-1.

The regulatory policy described by the mechanism design model is strictly preferred to the regulatory policy described by the pooling equilibria[7] if $\frac{2r}{F}(r+a^2-a^2r-1)>\frac{4a^2\lambda}{F}$. This condition holds when r is lower than a critical value r*, with $r^*=\frac{1}{2}+\frac{\sqrt{(a^2-1)(a^2-1-8a^2\lambda)}}{2(a^2-1)}$.[8]

Proposition 3: The welfare cost at the mechanism design equilibrium is strictly lower than at the pooling equilibria as long as $r<r^*$ with $r^*=\frac{1}{2}+\frac{\sqrt{(a^2-1)(a^2-1-8a^2\lambda)}}{2(a^2-1)}$.

The regulatory policy described by the mechanism design solution has a strictly lower expected regulatory cost than the regulatory policy described by the pooling equilibria of the signaling game as long as $r<r^*$. When the probability of low demand is small the regulatory policy that involves a more active attitude from the regulator is preferable. Furthermore, we conclude that the regulatory commitment is attractive from a social welfare perspective for a wide range of values of the probability of low demand (as r* is higher than a half). Once again we call attention to the fact that the result of Proposition 3 crucially depends on the assumption of many potential entrants. If we consider only one potential entrant we could not have developed the above analysis as we would have for the regulator a dichotomic decision.

With many potential entrants our analysis goes further than the replication of the signal

[7] Note that there is no doubt that the mechanism design implies a social welfare not below the one implied by the signaling model. This happens because with an active policy the regulator can always replicate the results of the signaling equilibria (see Kim (2010) for a detailed explanation applied to the entry regulation model). Hence, the relevant question under investigation is whether the mechanism design equilibria has a strictly higher social welfare than the signaling equlibria or not.

[8] Notice that for any admissible value of λ (ie, $\lambda<\lambda^{\max}$) the condition $(a^2-1)(a^2-1-8a^2\lambda)$ is positive.

equilibria outcomes as we evaluate the cost of the mechanism design for the optimal regulator's decision (which happens for the values of n_1 and n_2). This additional analysis would not be possible if we assume only one potential entrant.

Recovering the broader interpretation of entry regulation that we mention in the introduction, where we argue that entry regulation can be seen as the intensity of entry promotion contained in the regulatory decisions, we can give a more intuitive interpretation of the results. The decision of authorizing n^p-1 new firms can be interpreted as mild policy regarding entry: the regulator takes some actions to promote entry, but not very strong actions. On the contrary, authorizing n_2-1 new firms represents stronger decisions to stimulate entry (as eliminating slot rights in the air transport sector or imposing mandatory access to the incumbent firm's network on an equal basis in the electricity or telecommunications sectors, for instance), while authorizing n_1-1 new firms represents a weak policy regarding entry promotion. Then, when the regulator believes that the probability of low demand is small, it is better to adopt the stronger decision to stimulate entry (of course, not so strong as if the regulator was sure that demand was high, that here is represented by the authorization of n^H-1 new firms) than following a mild strategy, which has higher regulatory costs.

III. *Conclusions*

We show that the incumbent firm can use his superior knowledge of market demand to influence the entry regulatory policy.

Also we compare two regulatory policies to deal with the strategic behavior of incumbent firms. With the first policy the regulator has a passive behavior looking to the price fixed by the incumbent and taking it as a signal of the size of demand. In this signaling game there are two types of equilibria: one separating equilibrium under which the regulator authorizes the same number of new firms as with complete information, and multiple pooling equilibria where the regulator chooses the same number of new firms whatever the demand size, but different from what she would authorize with complete information. Hence, the pooling equilibria generate social welfare costs. We show that an equilibrium for such a game could be one where even if demand is high the incumbent firm fixes the price corresponding to low demand in order to send a signal to the regulator that will persuade him to make the entry of new firms difficult.

The other type of response from the regulator that we have considered demands a more active attitude. The regulator proposes a menu of contracts to the incumbent firm to create a mechanism that motivates the incumbent to tell the regulator the true demand size. This regulatory policy also generates social welfare costs as the number of new firms differs from the one of complete information.

Then, we compare the welfare costs of the two regulatory policies. Our conclusion is that for a wide range of values of the probability of low demand the social welfare is strictly higher with the more active regulatory policy. Therefore, in those contexts the regulator should pursue a stronger promotion of entry than a mild policy regarding entry promotion.

Moreover we conclude that considering many potential entrants has significant effects on entry regulation costs. With only one potential entrant Kim (2010) concludes that the ex-ante social welfare costs of the pooling equilibria, when it exists, is higher than under complete information. On the contrary, we show that with many entrants the pooling equilibria generate welfare costs. Besides, when the probability of low demand is low the welfare costs of the pooling equilibria are strictly higher than at the mechanism design equilibrium. Hence, under these circumstances the regulator should adopt a more proactive attitude regarding entry.

APPENDIX A — Proof of Proposition 1

Proposition 1 is parallel to the Proposition 1 of Kim (2010) and so it is the corresponding proof, that we summarized next. Consider the updated beliefs consistent with the separating strategy for the incumbent firm: $Prob(D^L\backslash p)=1$ if $p\in[0,\bar{p}]$, $Prob(D^L\backslash p)=0$ if $p\in(\bar{p},\infty)$. We consider that $\bar{p}<p_1^L$ because if $\bar{p}=p_1^L$ and demand were D^L the incumbent firm would choose p_1^L : he would maximize period's 1 profit and entry would be n^L-1; if demand were D^H the incumbent firm would also choose p_1^L since it is the closest price to p_1^H in the interval $[0,\bar{p}]$ and entry would be n^L-1. Therefore, the incumbent firm would follow a pooling strategy. First consider the incumbent firm's decision when D^L. If the incumbent firm chose a price in the interval $(\bar{p},\infty)$ then he would choose p_1^L to maximize the first period's profit and entry would be n^H-1. The incumbent firm's payoff would be $\pi_1^L(p_1^L)+\pi_2^L(n^H)$. If the incumbent firm chose a price in the interval $[0,\bar{p}]$ he would choose $\bar{p}$ and entry would be n^L-1. The incumbent firm's payoff would be $\pi_1^L(\bar{p})+\pi_2^L(n^L)$. The incumbent firm would choose $p\in[0,\bar{p}]$ if $\pi_1^L(\bar{p})+\pi_2^L(n^L)\geq\pi_1^L(p_1^L)+\pi_2^L(n^H)$. This condition is true when $\bar{p}\leq\frac{1}{2}+\frac{1}{2}\sqrt{1+4x}$ if $\frac{1}{2}-\frac{1}{2}\sqrt{1+4x}<0$ or when $\frac{1}{2}-\frac{1}{2}\sqrt{1+4x}\leq\bar{p}\leq\frac{1}{2}+\frac{1}{2}\sqrt{1+4x}$ if $\frac{1}{2}-\frac{1}{2}\sqrt{1+4x}>0$, with $x=\frac{1}{(\sqrt[3]{\frac{1}{F}})^2}-\frac{1}{(\sqrt{\frac{a^2}{F}})^2}-\frac{1}{4}$. Now consider the incumbent firm's decision when D^H. If the incumbent firm chose a price in the interval $(\bar{p},\infty)$ he would choose p_1^H to maximize the first period's profit and entry would be n^H-1. The incumbent firm's payoff would be $\pi_1^H(p_1^H)+\pi_2^H(n^H)$. If the incumbent firm chose a price in the interval $[0,\bar{p}]$ he would choose $\bar{p}$ and entry would be n^L-1. The incumbent firm's payoff would be $\pi_1^H(\bar{p})+\pi_2^H(n^L)$. Therefore, the incumbent firm would choose $p\in(\bar{p},\infty)$ if $\pi_1^H(p_1^H)+\pi_2^H(n^H)\geq\pi_1^H(\bar{p})+\pi_2^H(n^L)$. This condition is true when $\bar{p}\geq a(\frac{1}{2}+\frac{1}{2}\sqrt{1+4x})$ if $a(\frac{1}{2}-\frac{1}{2}\sqrt{1+x})<0$ or when i) $\bar{p}\leq a(\frac{1}{2}-\frac{1}{2}\sqrt{1+x})$ or ii) $\bar{p}\geq a(\frac{1}{2}+\frac{1}{2}\sqrt{1+x})$ if $a(\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})>0$. Combining the above conditions we conclude that:

- if $a(\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})<0$ (and consequently $\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})<0$ as $a>1$) there is not an equilibrium;
- if $a(\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})>0$ (and consequently $\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})>0$) there are equilibria when the price $\bar{p}$ is in the interval $\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})\leq\bar{p}\leq a(\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})$. However, by Cho and Kreps' Intuitive Criterion, all prices in the interval $\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})\leq\bar{p}\leq a(\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})$ are equilibrium dominated for D^H, and therefore only the strategy $\bar{p}=a(\frac{1}{2}-\frac{1}{2}\sqrt{1+4x})$ passes the Cho and Kreps' Intuitive Criterion.

Appendix B — Proof of Proposition 2

Assume the following updated beliefs consistent with the pooling equilibria described by Proposition 2 $Prob(D^L \mid p=r$ if $p \in [0, p^p]$ and $Prob(D^L \mid p=0$ if $p \in (p^p, \infty)$. With such beliefs the regulator would authorize $n^H - 1$ new firms if she observed $p \in (p^p, \infty)$. Otherwise, if the regulator observed $p \in [0, p^p]$ the number of authorized firms would be the one that maximizes the expected social welfare represented by:

$$E(W(n)) = rW^L(n) + (1-r)W^H(n)$$

From $\frac{d(E(W))}{dn} = 0$ the optimal value $n^p = (\frac{r + a^2 - a^2 r}{F})^{\frac{1}{3}} - 1$ is obtained.

Now it is necessary to prove that (p^p, p^p) with $p^p \in [\bar{p}, p_1^L]$ is the incumbent's best response to the regulator's strategy (n^p, n^H) and the updated beliefs.

First note that if $p^p < \bar{p}$ the incumbent firm with D^H would not mimic the incumbent firm with D^L (as we prove in Proposition 1), and therefore there is no pooling equilibria. To have pooling equilibria it is necessary that $p^p \geq \bar{p}$. If $p^p > p_1^L$ the incumbent firm with D^L would choose p_1^L and the incumbent firm with D^H would choose $p > p_1^L$, and then there is no pooling equilibria. For $\bar{p} \leq p^p \leq p_1^L$ the incumbent firm chooses p^p whatever the demand size. Then, there are multiple pooling equilibria, and they all pass the Intuitive Criterion of Cho and Kreps (1987).

Appendix C — Pooling equilibria with asymmetric information about demand and only one potential entrant

In our framework, if we assumed that there is only one potential entrant we would obtain a similar result as Kim (2010), that is, that the pooling equilibria only exist for some values of the prior probabilities. The proof is straightforward. With only one entrant the regulator's decision is dichotomic: to authorize entry or not authorize entry. Therefore, the regulator compares the expected value of social welfare under both scenarios, which are the following:

- entry: $E(W) = rW^L(n=2) + (1-r)\,W^H(n=2) = \frac{4}{9}(1-a^2)r + \frac{4}{9}a^2 - 2F$
- no entry: $E(W) = rW^L(n=1) + (1-r)W^H(n=1) = \frac{3}{8}(1-a^2)r + \frac{3}{8}a^2 - F$

The expected social welfare is higher with entry when $r < \frac{5a^2 - 72F}{5(a^2-1)}$ hence, in this interval, the regulator authorizes the entry of the potential entrant. Therefore, the incumbent firm cannot avoid entry.

References

Cho, I. and D. Kreps (1987), "Signaling Games and Stable Equilibria", *Quarterly Journal of Economics* 102, pp. 179-221.

Kim, J. (2010), "Optimality of Entry regulation under Incomplete Information", *Hitotsubashi Journal of Economics* vol. 51 no.2, pp. 99-113.

Laffont, J.-J. and J. Tirole (1993), *A Theory of Incentives in Procurement and Regulation*, MIT Press.

Lewis, T. and D. Sappington (1988), "Regulating a Monopolist with Unknown Demand", *American Economic Review* 78, pp. 986-989. Reprinted in P. Joskow, ed., (2000), *Economic Regulation*, Edward Elgar Publishing: Cheltenham, pp. 387-399.

Mankiw, N. and M. Whinston (1986), “Free Entry and Social Inefficiency”, *Rand Journal of Economics* 17 no.1, Spring, pp. 48-58. Reprinted in L. Cabral, ed., (2000), *Readings in Industrial Organization*, Blackwell Publishers: Oxford.

Milgrom, P. and J. Roberts (1982), “Limit Pricing and Entry under Incomplete Information: An Equilibrium Analysis”, *Econometrica* 50 no.2, pp. 443-459.

Myerson, R. (1979), “Incentive Compatibility and the Bargaining Problem”, *Econometrica* 47, pp. 61-73.

Newbery, D. (2000), *Restructuring and Regulation of Network Utilities*, MIT Press. First edition: 1999.

Stragier J. (2001), “Airline Alliances and Mergers: The Emerging Commission Policy”, Paper presented at the 13th Annual Conference of the European Air Law Association, Zurich, November.

Suzumura, K. and K. Kiyono (1987), “Entry Barriers and Economic Welfare”, *Review of Economic Studies* vol.54, 157-167.