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Entry mistakes with strategic pricing

Bernardino ADÃO *

ABSTRACT. – This paper concerns entry mistakes when the incumbent practices strategic pricing. Due to an agency problem between the owner and the manager of the entrant firm there may be equilibria with too much entry that are preferred by both the entrant and the incumbent. This result is surprising because it would be expected that the entrant would prefer to know the type of incumbent in the industry before he takes his decision.

Erreur d'entrée avec la fixation stratégique de prix

RÉSUMÉ. – Cet article traite des erreurs d'entrée lorsque le concurrent en place pratique la fixation stratégique de prix. Un problème d'asymétrie d'information entre l'actionnaire et le gérant de la société candidate à l'entrée peut conduire à des équilibres où trop d'entrées sont souhaitées simultanément par le nouveau concurrent et par le concurrent en place. Ce résultat est surprenant car on pourrait espérer que le nouveau venu préfère connaître le type de concurrent déjà présent dans l'industrie avant de prendre sa décision.

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[2] Departamento de Estudos Económicos, Banco de Portugal, Av. Almirante Reis, 71, 1150 Lisboa, Portugal, Phone: 351-213128409, E-mail: badao@bportugal.pt.

1 Introduction

This paper studies the possibility of entry mistakes (*i.e.* entries that cannot be sustained by the market) being optimal when the incumbent strategic variable to block entry is the price. There is evidence that firms use prices to make entry more difficult. SMILEY [1988] surveys 293 product managers and similarly placed executives in manufacturing and service industry firms and reports that almost everyone admitted making occasional use of entry deterrence practices. About 58 percent of the respondents reported using frequently deterrence practices in their industry to defend existing products, and 16 percent of these reported frequent use of limit-pricing strategy to protect existing products. SINGH *et al.* [1998] conducted a similar survey in the food, electrical engineering and chemical industries and verified that 63 percent of the respondents reported the pricing policy to have high priority as a strategic variable to slow down or dissuade new products.

Moreover, the likelihood of occurring entry mistakes is non-negligible. Entrants are known to be many and to have an extremely high mortality rate. DUNNE *et al.* [1988] calculated that entrants from one Census of Manufactures year to the next, a 5 year period, averaged 38.6 percent of the number of firms in an industry. They calculate that about 60 percent of the firms entering U.S. manufacturing in a given Census year exit before the next Census year. MATA *et al.* [1995] computed that about 10% of the operating firms in a given year did not exist in the previous year, and of those that entered, 20% will leave after the first year.

An important reason for an entrant to fail has to do with his lack of experience in the industry where he opens the new plant. MATA *et al.* [1995] analyse the survival histories of plants created by already established firms by distinguishing between those whose parent firm was already operating a plant in the industry in which the new plant starts, which they call an experienced entry, and those whose parent company has no activities in the industry, which they call a diversified entry. They verified that the 7 year survival rate of experienced entries exceeds that of diversified entries by about 15 percent and the 7 year hazard rate of diversified entries exceeds that of experienced entries by about 18 percent.

The negative correlation between experience and entry failure is an indication that the probability of an entry mistake is larger when there are more uncertainties about the industry environment. In the model this feature of the real world is considered as the entrant is assumed to be unsure about the incumbent's input costs and about the incumbent's degree of efficiency. The incumbent may be able to increase the entrant's uncertainty about the industry environment by strategically using prices.

MILGROM and ROBERTS [1982] were the first to model the established firm and potential entrant as maximizing decision-makers in a game theoretical form. In the MILGROM and ROBERTS [1982] model, because the incumbent prefers to be a monopoly, he wants to convey the information that he has a low cost. The problem is that he has no direct means of doing so, even if he indeed has a low cost. The indirect way is to signal by producing a large pre-entry quantity. But a high pre-entry quantity may not deter entry, since knowing that it is in the incumbent self interest to produce such a quantity, a rational entrant will not necessarily infer that the incumbent has a low cost. The surprising result in MILGROM and ROBERTS [1982] is that there will be two types of equilibria, separating and pooling. In the separating equilibria the pre-entry price reveals the incumbent's cost level and entry occurs as in a perfect-information model, in which nature moves first to determine the incumbent's cost and the potential entrant is informed of the result. In the pooling equilibria the pre-entry price does not reveal completely the incumbent's cost level.

In the case of a pooling equilibrium, *ex-post* the entrant may make a mistake. The *ex-post* mistake can be of two types: entering when he should not have entered or not entering when he should have entered. We will be concerned with the first type of mistake. A sufficient condition for this type of mistake to occur is that the prior probability assigned to the incumbent being of the high cost type is large enough that there is entry for a pooling pre-entry price.

The high level of entry failure we observe in the real world is associated with a waste of resources. Nevertheless, we argue, in a second best world might be preferable to have entries that *ex-ante* are not completely safe than entries that *ex-ante* are completely safe. This paper shows that entry mistakes might be a Pareto outcome, *i.e.* preferred by both the incumbent and the entrant. The argument is done in the context of the MILGROM and ROBERTS [1982] signalling game.

With no asymmetric information between the manager and the owner of the entrant firm, the entrant always prefers a separating sequential equilibrium, which is revealing, to any pooling sequential equilibrium, which is non-revealing, since in that case he learns whether it is profitable to enter. With asymmetric information the sum of the manager's rent and the owner's dividend payment may be larger in a pooling sequential equilibrium than in a separating equilibrium because the optimal contract between the manager and the owner depends on the equilibrium strategy adopted by the incumbent firm. In a pooling sequential equilibrium, the entrant does not learn the incumbent's type and the manager does not get a rent. In a separating equilibrium, the manager learns the incumbent's type. The manager can use this additional information to extract a rent.

The result of this paper can be seen as just an example of the general principle that in situations of strategic interaction one player may gain from having less information. In the situation we analyse, less information about the incumbent's efficiency for both the manager and the owner alleviates their asymmetric information problem about the incumbent's cost which may benefit the entrant firm.

The remaining of the paper is organized as follows. The next section gives the details of the model. Section 3 discusses the equilibrium when there is no asymmetric information between the manager and the owner. Section 4 describes the equilibrium when there is asymmetric information between the manager and the owner. And section 5 states the conclusions.

2 Model

There are 2 periods and 3 risk neutral decision makers. They are, an incumbent, a manager and a owner. The entrant is a contract between a owner and a manager that maximizes the dividends received by the owner subject to participation and incentive compatibility constraints for the manager. The incumbent is a monopolist in period 1 that chooses a first period quantity y. In period 2, after observing the first period price, the entrant decides whether to enter. There is Cournot competition in the second period if there was entry. Otherwise the incumbent remains a monopolist.

Marginal costs are assumed to be constant. The incumbent's marginal cost is $\theta_t c_i$. The parameter θ_t reflects incumbent's input costs, that may change between periods (θ_t, $t = 1,2$). It is assumed that θ_2 is a random variable with support $[\underline{\theta},\overline{\theta}] \equiv \Theta$, distribution function F, and density f. To simplify the analysis it is assumed away any uncertainty in θ_1 as it does not add anything to the analysis but complicates the notation. The parameter c_i denotes the efficiency degree of the incumbent. The incumbent's c_i can be low ($= c_L$ with probability x) or high ($= c_H$ with probability $1 - x$). The entrant's marginal cost is k.[3]

The firms' output is assumed to be homogeneous. The demand in period t ($= 1,2$) is assumed to be linear, with slope one and intercept one.[4] The manager produces quantity e and the incumbent second period quantity q. While quantities are private information to the manager and the incumbent, the price in each period is publicly known. The gross profit belongs to the manager who compensates the owner with a dividend payment D.

The timing of the events is the following: (i) Nature chooses θ_2 and c_i; (ii) The incumbent learns c_i and decides to produce first period quantity $\sigma(c_i)$; (iii) The owner and the manager observe period one market price p_1 and decide whether to enter. If entry occurs the entrant pays an entry cost equal to E; (iv) In case of entry a contract between the owner and the manager is designed. The incumbent and the manager learn θ_2. The manager reports θ_2 to the owner. Simultaneously, the incumbent and the manager decide second period production levels;[5] (v) Dividends are paid, the second period price is observed and if the manager was found not to have complied with the contract he then pays a penalty.

Let $\Pi^{A,I}(c_i,\theta_t,y)$ denote the incumbent's period t profit when he is of type c_i, produces y and is alone in the industry, for $t = 1,2$ and $i = L$ or H, $\Pi^{T,I}(c_i,\theta_2,\mu)$ and $\Pi^{T,E}(c_i,\theta_2,\mu)$ denote the incumbent's duopoly profit

3. Instead, taking k unknown to the incumbent would only complicate the notation.

4. Instead of assuming constant marginal costs, linear demand, and an homogeneous product we could have assumed more complicated structures, but that would only complicate the analysis without changing the main results.

5. Milgrom and Roberts assume that once entry has actually occurred, the private information about the incumbent's cost is truthfully revealed to the entrant, therefore the entrant's production decision is taken only after the incumbent's cost is learned. Here, this assumption is dropped. The entrant decides how much to produce without knowing the incumbent's cost. Thus, the duopoly profits of the incumbent and of the entrant in the second period depend on the entrant's beliefs.

and the entrant's duopoly profit respectively when the incumbent is of type c_i, and the entrant has posterior beliefs μ about the incumbent being of the low cost type.

We restrict the analysis in two ways:

(1) $$\Pi^{T,E}(c_H,\underline{\theta},\mu = 0) \geqslant E \geqslant \Pi^{T,E}(c_L,\overline{\theta},\mu = 1);$$

(2) $$x\Pi^{T,E}(c_L,\underline{\theta},\mu = x) + (1 - x)\Pi^{T,E}(c_H,\underline{\theta},\mu = x) > E.$$

The first restriction gives importance to the interaction between incumbent and entrant. Says that under perfect information, if the incumbent is low cost there is no entry but if he is high cost there is entry. And the second is needed so that there is always entry when the entrant learns nothing about what is the established firm's type.

The notion of sequential equilibrium is described next. Define $G(\mu)$ as the second period simultaneous move quantity setting game when the conjecture about the incumbent being of the low cost type is μ. Under the specifications given above, the subgame $G(\mu)$ has a unique Nash equilibrium for each μ. The first period quantity setting strategy of the incumbent firm is a function $\sigma : c_L \otimes c_H \longrightarrow R^2_+$. The production decision of the potential entrant is a function $e : \Theta \otimes R_+ \longrightarrow R_+$.

By a pure strategy sequential equilibrium, we mean a tuple of strategy profiles (σ,e) and a system of beliefs μ satisfying the following assumptions:

(a) For $y \geqslant 0$ that is used by σ, the strategies of both players in the subgame $G(\mu)$ must be a Nash equilibrium and, $e(\theta_2,y) > 0$ if and only if $\mu^y \int_\Theta D(c_L,\theta_2,\mu^y)dF(\theta_2) + (1 - \mu^y) \int_\Theta D(c_H,\theta_2,\mu^y)dF(\theta_2) \geqslant E$;

(b) for e and all $(\theta_2,c_i) \in \Theta \otimes \{c_L,c_H\}$, $\sigma(c_i) \in \arg\max_y \{y(1 - y - \theta_1 c_i) + B(c_i,\mu^y)\}$, where

$B(c_i,\mu^y) = \int_\Theta \left\{\Pi^{A,I}(c_i,\theta_2)[1 - \mathtt{I}_{e>0}] + \Pi^{T,I}(c_i,\theta_2,\mu^y)\mathtt{I}_{e>0}\right\} dF(\theta_2)$

where $\mathtt{I}$ is an indicator function. Note that according to this formalization it is implicit that the incumbent assumes that the contract between the owner and the manager is incentive compatible;

(c) if the quantity y is used with positive probability by σ, then μ^y must be computed by Bayes' rule.

The first two conditions are sequential rationality requirements for the equilibrium strategies of both players, the entrant and the incumbent. The last condition is a consistency restriction on the beliefs. Notice that if y is not used with positive probability, then consistency imposes no *a priori* restriction over μ.

In general there are many sequential equilibria, some more reasonable than others. That fact as to do, some say, with the inability of the sequential equilibrium concept to adequately restrict out-of-equilibrium beliefs. This freedom to choose beliefs off-the-equilibrium path typically results in a large number of sequential equilibria. By now there is a large literature on how to restrict those out-of-equilibrium beliefs so that many nonplausible sequential equilibria may be eliminated.

The dominant view is that sequential equilibria that seem unreasonable should be refined away. Stability (see KOHLBERG and MERTENS [1986]) is defined by requiring a "good" outcome to have nearby "good" outcomes in games close by, where only payoffs are being perturbed. Undefeatedness (see MAILATH *et al.* [1993]) is defined by requiring a "good" outcome to have nearby "good" outcomes in games close by, where only the distribution of types is being perturbed. Stability and undefeatedness are important properties, and that any sequential equilibrium that possesses one of these properties should be taken as a more plausible outcome of the game than one sequential equilibrium that does not satisfy any of them.

The literature on signalling games has payed special attention to the stability criterion. Most papers have used the intuitive criteria, as defined in CHO and KREPS [1987], to restrict the set of sequential equilibria.[6] Given a sequential equilibrium, if there is a disequilibrium first period quantity y' and if there is a type who would never want to produce this first period quantity because regardless of the beliefs the entrant would form after observing quantity y', this type would obtain a smaller payoff than had the original equilibrium being played. And if further the entrant believed that y' was chosen by the other type, then any best response by the entrant yields a higher payoff than in the original equilibrium to that type. Then the original equilibrium fails the intuitive criterion.

The test a sequential equilibrium as to pass to be undefeated is the following. Consider a proposed sequential equilibrium and a first period quantity for the incumbent that is not played in that particular equilibrium. Suppose there is an alternative equilibrium in which some non-empty set of incumbents chooses the given quantity and that set is precisely the set of types that prefers the alternative equilibrium to the proposed equilibrium. The test requires the entrant's beliefs to be consistent with this set. If the beliefs are not consistent the second equilibrium defeats the proposed equilibrium.

3 No Asymmetric Information between Manager and Owner

As already referred the model with no asymmetric information between the manager and the owner of the entrant firm was first studied by MILGROM and ROBERTS [1982]. Various graduate textbooks present clear analyses of this game, just to mention a few, TIROLE [1988] pages 367-374, KREPS [1990] pages 468-480, and VARIAN [1992] pages 308-310. As such this section will be concise and the reader referred to the literature for the proofs.

We will be looking for sequential equilibria in pure strategies. That equilibria can be categorized in 2 classes: separating or pooling. In a separating equilibrium, the incumbent does not pick the same first period quantity when his cost is low as when it is high. The first period price then fully reveals the cost to the entrant. In a pooling equilibrium, the first period quantity is inde-

6. The intuitive criterion is a subset of the set of stable equilibria which is defined for all games rather than only signalling games, and is defined without reference to restrictions on beliefs.

pendent of the cost level. The entrant then learns nothing about the cost, and his posterior beliefs are identical to his prior beliefs *i.e.* $\mu = x$.

There are two necessary conditions for a pair of first period quantities to be part of a separating equilibrium: that the low cost type does not want to pick up the high cost type's equilibrium quantity, and *vice-versa*. The beliefs for quantities that differ from the two potential equilibrium quantities (*i.e.* are off the equilibrium path) must be such that prevent the two types from deviating from their equilibrium quantities. In this case the necessary conditions are also sufficient, in the sense that the corresponding quantities are equilibrium quantities. Separating equilibria always exist. The proof of this result follows from a straightforward adaptation of the arguments in Tirole's book.

Because it will be useful in the next section, we now formalize the analysis of separating equilibria. In a separating equilibrium, the high cost type's quantity induces entry. He thus produces the monopoly quantity $y^{H,M}$ in the first period and gets $\Pi^{A,I}(c_H,\theta_1,y^{H,M}) + \int_\Theta \Pi^{T,I}(c_H,\theta_2,\mu = 0)dF(\theta_2)$. Let y^S denote the quantity of the low cost type in the separating equilibrium. The high cost type by producing this quantity, deters entry and obtains $\Pi^{A,I}(c_H,\theta_1,y^S) + \int_\Theta \Pi^{A,I}(c_H,\theta_2,q^{H,M})dF(\theta_2)$, where $q^{H,M}$ is the monopoly quantity in the second period. Thus a necessary condition for equilibrium is,

$$\begin{aligned}\Pi^{A,I}(c_H,\theta_1,y^{H,M}) + \int_\Theta \Pi^{T,I}(c_H,\theta_2,\mu = 0)dF(\theta_2) \geqslant \\ \Pi^{A,I}(c_H,\theta_1,y^S) + \int_\Theta \Pi^{A,I}(c_H,\theta_2,q^{H,M})dF(\theta_2).\end{aligned} \tag{3}$$

Similarly the low cost type must be maximizing his profit by choosing y^S. In equilibrium he gets $\Pi^{A,I}(c_L,\theta_1,y^S)+\int_\Theta \Pi^{A,I}(c_L,\theta_2,q^{L,M})\,dF(\theta_2)$ (where $q^{L,M}$ is the monopoly quantity in the second period) and if he produces the first period monopoly quantity $y^{L,M}$ he gets at worst $\Pi^{A,I}(c_L,\theta_1,y^{L,M}) + \int_\Theta \Pi^{T,I}(c_L,\theta_2,\mu = 0)dF(\theta_2)$, and so another necessary condition for equilibrium is,

$$\begin{aligned}\Pi^{A,I}(c_L,\theta_1,y^S) + \int_\Theta \Pi^{A,I}(c_L,\theta_2,q^{L,M})dF(\theta_2) \geqslant \\ \Pi^{A,I}(c_L,\theta_1,y^{L,M}) + \int_\Theta \Pi^{T,I}(c_L,\theta_2,\mu = 0)dF(\theta_2).\end{aligned} \tag{4}$$

A condition for the a first period quantity to be part of a pooling equilibrium is that none of the types wants to choose its monopoly quantity instead. Another condition is that the posterior beliefs be such that prevent the two types from deviating from their equilibrium quantity. It is easy to verify, through a straightforward adaptation of the arguments in Tirole's book that under certain conditions pooling equilibria do exist, too.

A necessary condition for the first period quantity y^P (when $y^P \neq y^{L,M}$) to be part of a pooling equilibrium is that none of the types wants to choose its monopoly quantity. If one of them were to do so, it would at worst allow entry with beliefs $\mu = 0$,

$$\Pi^{A,I}(c_L,\theta_1,y^{L,M}) + \int_{\Theta} \Pi^{T,I}(c_L,\theta_2,\mu=0)dF(\theta_2) \leqslant \Pi^{A,I}(c_L,\theta_1,y^P) + \int_{\Theta} \Pi^{T,I}(c_L,\theta_2,\mu=x)dF(\theta_2) \tag{5}$$

$$\Pi^{A,I}(c_H,\theta_1,y^{H,M}) + \int_{\Theta} \Pi^{T,I}(c_H,\theta_2,\mu=0)dF(\theta_2) \leqslant \Pi^{A,I}(c_H,\theta_1,y^P) + \int_{\Theta} \Pi^{T,I}(c_H,\theta_2,\mu=x)dF(\theta_2) \tag{6}$$

In this particular game the intuitive criterion is very potent. There is just one equilibrium that is not eliminated by it. That equilibrium is often called the Riley equilibrium, and is characterized for being the separating equilibrium the low cost type of incumbent prefers the most. The proof that the Riley equilibrium is the only separating equilibria that survives the intuitive criterion is trivial. The proof that no pooling equilibria satisfies the intuitive criterion is more involved. As we could not find a reference in the literature for the proof we include it in the appendix.

LEMMA 1. *No pooling equilibria satisfies the intuitive criterion.*

PROOF : See appendix.

The set of separating equilibria will remain unchanged as the proportion of low incumbents in the population decreases, with the Riley equilibrium being the only one passing the intuitive test. While the equilibrium selected by the intuitive criterion remains unchanged for any positive proportion of low cost incumbents, the situation is quite different when there are no low cost incumbents. In this case the incumbent chooses in the first period its monopoly quantity. This discontinuity with respect to the types of incumbent is somewhat disturbing. The predicted outcome is overly sensitive to the description of the environment. The concept of undefeated equilibrium addresses this difficulty.

It follows immediately from the definition that the set of undefeated equilibria of this particular game can either be the Riley equilibrium or a set of pooling equilibria. When the low cost type of incumbent prefers the Riley equilibrium to any pooling equilibrium then the Riley equilibrium is the only outcome of the game that is undefeated. Otherwise, all pooling equilibria that are preferred to the Riley by the low cost type of incumbent equilibrium and not Pareto dominated (by another pooling equilibrium) are undefeated.

We now stress the main results of this section. There are two types of equilibrium: pooling and separating. Pooling equilibria do not satisfy simultaneously the intuitive and the undefeatedness criterion. They never satisfy the first criterion but they can satisfy the second. Under the point of view of an entrant a pooling equilibrium outcome is dominated by any separating equilibrium outcome as the entrant always prefers to know the type of incumbent. Under the point of view of the installed firm a pooling equilibrium outcome is always preferred by the high cost type and it may also be preferred by the low cost type to any separating equilibrium.

4 Asymmetric Information between Manager and Shareholder

It is widely accepted that owners are less well informed than current firm insiders, about firm's decisions and market conditions, see for instance GRIMBLATT and TITMAN [1998] and references therein. Here, we assume that the product's price and firm's marginal cost are known to the owner. The owner does not observe the quantity produced by his firm and does not observe the incumbent's marginal cost.

The manager decides the quantity produced by the firm and has more knowledge about the inputs costs than the owner. This is portrayed by having the manager observing θ_2 (which for simplicity from now on will be denoted by θ), but not the owner. In a separating equilibrium in which the incumbent signals to be of the low cost type, the quantity produced by the entrant will be zero, by virtue of condition (1). In a separating equilibrium in which the incumbent signals to be of the high cost type there may be entry by condition (1). There will be entry only if the expected profit exceeds the entry cost. In what follows we assume that is the case. In a pooling equilibrium the quantity produced by the entrant will be positive by condition (2), and the manager reports the true second period demand intercept parameter to the owner. Otherwise he is caught lying with positive probability. As long as the manager can be sufficiently penalized he does not deceive the owner.[7]

The dividend payment to the owner is not trivial in case the incumbent reveals to be of the high cost type and we characterize the dividend payment to the owner in this case. The dividend payment, $\mathfrak{D}$, that will be paid to the owner depends on the manager's report of the second period demand intercept θ, and on the second period observed price p_2 (which for simplicity from now on will be denoted by p), *i.e.* $\mathfrak{D}(\theta, p)$.

From the revelation principle we know that we can restrict ourselves to a direct revelation mechanism that induces truth-telling by the manager, *i.e.* to a revelation mechanism such that the manager's optimal strategy is reporting $\theta = \hat{\theta}$, where $\hat{\theta}$ is the true cost parameter. Thus, the second period price will be a function of the cost parameter reported by the manager, *i.e.*

7. The manager could not make sure, when lying about θ, that the price will always match an admissible price $p(c,\theta) = 1 - q(c,\theta) - e(\theta)$. If the true intercept shock is $\hat{\theta}$, the manager could not pretend it is θ by setting an output $\widetilde{e}$ such that, whatever c, the realized price matches one of the equilibrium prices, thereby avoiding detection with probability one. In this particular setting the reduced information generated by the pooling equilibrium about the incumbent's cost does eliminate the asymmetric information problem. The manager should choose $\widetilde{e}$ such that $1 - q(c,\hat{\theta}) - \widetilde{e} = 1 - q(c,\theta) - e(\theta)$, solving for $\widetilde{e}$ one obtains

$$\begin{aligned}\widetilde{e} &= q(c,\theta) - q(c,\hat{\theta}) + e(\theta)\\ &= \frac{e(\hat{\theta}) + c\hat{\theta} - e(\theta) - c\theta}{2} + e(\theta)\\ &= \frac{e(\hat{\theta}) + e(\theta) + c\left(\hat{\theta} - \theta\right)}{2},\end{aligned}$$

which depends on c.

$p(\theta) = 1 - q(\theta) - e(\theta),$ where q is the incumbent's second period production and e the entrant's second period production. Therefore, the dividend payment can be written as a function of θ only, *i.e.* $\mathfrak{D}(\theta, p(\theta)) = D(\theta)$.

Let $\{e(\theta), D(\theta)\}_{\theta\in\Theta}$ be such a revelation mechanism, where θ denotes the report. As we have done before we will call to such a pair a contract. A contract $\{e(\theta), D(\theta)\}_{\theta\in\Theta}$ solves the following program:

$$\max_{\{e(\theta), D(\theta)\}} \int_{\Theta} D(\theta) dF(\theta),$$

subject to,

$$U(\theta) \equiv (p(\theta) - k)e(\theta) - D(\theta) \geqslant 0, \tag{7}$$

$$\theta \in \arg\max\{(p(\theta) - k)e(\theta|\hat{\theta}) - D(\theta)\}, \tag{8}$$

where $U(\theta)$ is the manager's payment, $e(\theta|\hat{\theta}) = q(\theta) - q(\hat{\theta}) + e(\theta),$ condition (7) is a participation constraint and condition (8) is an incentive compatibility constraint.[8] In this problem $q(\theta)$ is an exogenous variable which is not observable by the owner. The manager's payment $U(\theta)$, becomes determined given the price level $p(\theta)$ and the dividend $D(\theta),$ which are both observable by the owner.

The incentive compatibility condition implies that $U(\hat{\theta}) \equiv \max_{\{\theta\}} \left\{(p(\theta) - k)e(\theta|\hat{\theta}) - D(\theta)\right\}$. This yields a first order condition,

$$[p(\theta) - k]e'(\theta|\hat{\theta}) + [-q'(\theta) - e'(\theta)]e(\theta|\hat{\theta}) - D'(\theta) = 0,$$

which, using truth-telling and the equation for $e(\theta|\hat{\theta}),$ can be simplified to

$$U'(\theta) = [p(\theta) - k][-q'(\theta)]. \tag{9}$$

A second order condition is,

$$[p(\theta) - k]e''(\theta|\hat{\theta}) + 2p'(\theta)e'(\theta|\hat{\theta}) \leqslant -p''(\theta)e(\theta|\hat{\theta}) + D''(\theta). \tag{10}$$

By differentiating (9) with respect to θ, one obtains

$$-p''(\theta)e(\theta) + D''(\theta) = q'(\theta)p'(\theta) - p''(\theta)[p(\theta) - k] + 2p'(\theta)e'(\theta). \tag{11}$$

Using truth-telling and equation (11) in equation (10) one gets, $p'(\theta)q'(\theta) \leqslant 0$. Since $q'(\theta) < 0$, the second order condition is equivalent to $q'(\theta) + e'(\theta) \leqslant 0$.

Thus, the optimization program can be rewritten as:

$$\max_{\{e(\theta), D(\theta)\}} \int_{\Theta} D(\theta) dF(\theta),$$

8. The incentive compatibility condition can be used to show that $U(\theta)$, $e(\theta)$ and $D(\theta)$ are almost everywhere differentiable.

subject to

$$U(\theta) \geqslant 0 \; for \; all \; \theta \in \Theta, \tag{12}$$

$$U'(\theta) = [p(\theta) - k][-q'(\theta)], \tag{13}$$

$$e'(\theta) \leqslant -q'(\theta). \tag{14}$$

We make the problem above less constrained by ignoring the local second order condition (14). Naturally, we'll check that the ignored constrained is indeed satisfied by the solution of the less constrained problem.

Let θ^* be such that $p(\theta) - k > 0$ for $\theta > \theta^*$ and $p(\theta) - k < 0$ for $\theta < \theta^*$. As $q'(\theta) < 0$, $U(\theta^*) = 0$ is a necessary optimality condition. Let $U(\underline{\theta}) = \int_{\underline{\theta}}^{\theta^*} [p(t) - k][-q'(t)]dt \equiv u_0$. Integrating by parts the expected utility for the manager we get

$$\begin{aligned}
\int_{\Theta} U(\theta) dF(\theta) &= \int_{\Theta} \{u_0 + \int_{\underline{\theta}}^{\theta} [p(t) - k][-q'(t)]dt\} dF(\theta) \\
&= u_0 + \left[F(\theta) \int_{\underline{\theta}}^{\theta} [p(t) - k][-q'(t)]dt \right]_{\underline{\theta}}^{\overline{\theta}} \\
&\qquad - \int_{\Theta} F(\theta)[p(\theta) - k][-q'(\theta)]d\theta \\
&= u_0 + \int_{\underline{\theta}}^{\overline{\theta}} [p(\theta) - k][-q'(\theta)]d\theta \\
&\qquad - \int_{\Theta} F(\theta)[p(\theta) - k][-q'(\theta)]d\theta \\
&= u_0 + \int_{\Theta} \frac{1 - F(\theta)}{f(\theta)} [p(\theta) - k][-q'(\theta)] dF(\theta)
\end{aligned}$$

Substituting in the objective function of the optimization problem we obtain

$$\max_{\{e(\theta)\}} \int_{\Theta} \{[p(\theta) - k]e(\theta) + \frac{1 - F(\theta)}{f(\theta)} [p(\theta) - k] q'(\theta)\} dF(\theta) - u_0.$$

A first order condition of this problem is

$$p(\theta) - e(\theta) - k - \frac{1 - F(\theta)}{f(\theta)} q'(\theta) = 0. \tag{15}$$

This condition combined with the incumbent's reaction function:

$$p(\theta) - q(\theta) - c\theta = 0, \tag{16}$$

characterizes the solution.

After solving (16) for $q(\theta)$ and $q'(\theta)$, and substituting in (15) one gets

$$\frac{1}{2} - \frac{3e(\theta)}{2} + \frac{c\theta}{2} - k + \frac{1 - F(\theta)}{f(\theta)}\left(\frac{e'(\theta) + c}{2}\right) = 0 \tag{17}$$

When $\theta = \overline{\theta}$, (17) implies $e(\overline{\theta}) = \frac{1+c\overline{\theta}-2k}{3}$. Thus, (17) can be written as

$$3\frac{e(\overline{\theta}) - e(\theta)}{2} + \frac{c\left(\theta - \overline{\theta}\right)}{2} + \frac{1 - F(\theta)}{f(\theta)}\frac{\left(e'(\theta) + c\right)}{2} = 0 \tag{18}$$

From now on we will take that the density function is uniform,[9] *i.e.* $f = \frac{1}{\overline{\theta}-\underline{\theta}}$. Equation (18) becomes

$$\int_{\theta}^{\overline{\theta}} \left(e'(\theta) + 3e'(t)\right) dt = 0,\ for\ all\ \theta \in \Theta.$$

This implies $e(\theta) = e(\overline{\theta})$. Otherwise $e'(\theta) \neq 0$ on some nonzero measure set. Let $[\theta_1,\theta_2]$ be an interval in Θ, so that $e'(\theta) > 0$ for any $\theta \in [\theta_1,\theta_2]$ or $e'(\theta) < 0$ for any $\theta \in [\theta_1,\theta_2]$ and θ_2 such that $\int_{\theta_2}^{\bar{\theta}} e'(t)dt = 0$. But then, we must have $\int_{\theta}^{\bar{\theta}} [e'(t) + 3e'(\theta)]dt \neq 0$ for $\theta \in [\theta_1,\theta_2)$ which is a contradiction.

Thus when the distribution is uniform and the separating equilibrium indicates the incumbent is of the high cost type the second period equilibrium quantities for the entrant and the incumbent are: $e(\theta) = \frac{1+\bar{\theta}c_H-2k}{3}$ and $q(\theta) = \frac{1+k}{3} - c_H\left(\frac{\bar{\theta}}{6} + \frac{\theta}{2}\right)$. It is easy to verify that the second order condition (14) is satisfied with strict inequality as $e' = 0$ and $q' = \frac{-c}{2}$.[10]

We now assume, to simplify the discussion that follows, that there is no separating equilibrium in which each type behaves as in a full information context, *i.e.* the high cost type would wish to pool if the low cost monopoly quantity was part of a separating equilibrium.[11] Under this assumption the smallest first period quantity for a low cost incumbent that satisfies (3) and (4) is the first period quantity for the low cost type in the Riley equilibrium.

The next proposition compares the Riley equilibrium obtained in an environment in which the manager of the entrant firm has no private information with the Riley equilibrium obtained in an environment in which the manager of the entrant firm has private information. Let y_N^L denote the first period

9. Besides being a reasonable distribution function to represent the uncertainty about input prices it allows an explicit solution. That is enough for our purposes as we do not pretend to study exhaustively all the regions of parameters for which the main result of the paper holds.

10. As $\Pi(\theta)$ is strictly increasing in θ, the inverse function h, which is defined as $\theta = h(\Pi)$ does exist. Obviously h is an increasing linear function of Π. Thus, U and D are a function of the level of profits.

11. This assumption is sufficient to get sequential equilibria with limit pricing.

quantity in the Riley equilibrium for the low cost type in an environment with no asymmetric information and let y_A^L denote the first period quantity in the Riley equilibrium for the low cost type in an environment with asymmetric information. The Riley equilibrium allocation in an environment in which the entrant firm's manager does not have private information yields: a pair of first period productions, y_N^L and $.5(1-\theta_1 c_H))$ for the low cost type incumbent and high cost type incumbent, respectively, an entrant firm's production $1/3(1+\theta_2 c_H-2k)$, a pair of second period productions $.5(1-\theta_2 c_L)$ and $1/3(1+k-2\theta_2 c_H)$ for the low cost type incumbent and high cost type incumbent, respectively, and in the case of entry second period total production $1/3(2-k-\theta_2 c_H)$. The Riley equilibrium in an environment in which the entrant firm's manager has private information yields: a pair of first period productions y_A^L and $.5(1-\theta_1 c_H)$ for the low cost type incumbent and the high cost type incumbent, respectively, an entrant firm's production $1/3(1+\bar{\theta}c_H-2k)$, a pair of second period productions $.5(\theta_2-c_L)$ and $\left(\frac{1+k}{3}-c_H\left(\frac{\bar{\theta}}{6}+\frac{\theta_2}{2}\right)\right)$ for the low cost type incumbent and high cost type incumbent, respectively, and in the case of entry second period total production $\frac{2-k}{3}-\frac{3\theta_2-\bar{\theta}}{6}c_H$.

PROPOSITION 1. *Comparison of the Riley allocation obtained in an environment in which the manager of the entrant firm has no private information with the Riley allocation obtained when the manager of the entrant firm has private information gives the following, (a) the high cost incumbent firm, in the asymmetric information environment, produces less in the second period, (b) the entrant produces more in the asymmetric information environment, (c) second period total production is higher in the asymmetric information environment, (d) the first period production for the low cost type is higher in the asymmetric information environment, i.e.* $y_A^L > y_N^L$.

PROOF : Results (a), (b) and (c) follow from our discussion above. Result (d) follows from the fact that the left hand side of inequality (3) is smaller in the environment with asymmetric information and from the fact that for condition (3) to be satisfied the first period production, y^S, for the low cost type much be higher.

In the case of a pooling equilibrium as long as the manager can be penalized when the owner discovered he told a lie no rents need to be paid to the manager. Moreover the production level of the entrant firm would be the same as if there was no asymmetry of information between the manager and the owner.

PROPOSITION 2. *The set of pooling sequential equilibria in the environment with asymmetric information is larger than the set of pooling sequential equilibria in the environment without asymmetric information. Moreover, the likelihood of having the undefeated criterion selecting a pooling equilibrium as the unique outcome is higher in the environment with private information between the manager and the owner of the entrant firm.*

PROOF : To prove the first part of the proposition just notice that the left hand sides of inequalities (5) and (6) are strictly smaller in an environment in which the manager does have private information, which implies that the set of first period quantities y^P that satisfies (5) and (6) is strictly larger. The second part of the proposition follows from the fact that the set of pooling equilibria in the environment with asymmetric information includes equilibria with first period quantities that are closer to quantity $y^{L,M}$ and from the fact that the Riley equilibrium has a higher first period quantity for the low cost type further way from $y^{L,M}$ in the environment with asymmetric information.

Next, we show the existence of a pooling equilibrium that both the entrant and the incumbent prefer to any sequential equilibrium.

PROPOSITION 3. *For some parametrizations there are pooling equilibrium that both the entrant and the incumbent prefer to any separating equilibria.*

PROOF : To demonstrate existence we only need to consider the following example. Suppose that the parameters of the model are as follows: (i) $\theta_1 = .5$, $\theta_2 \in [.5; 1.5]$; (ii) $c_L = .05$ and $c_H = .18$; (iii) $k = .54$; (iv) $x \approx 0$; (v) $E < .003$. For these parameters there is entry in a pooling equilibrium and in a separating equilibrium. There is a pooling equilibrium with first period quantity equal to the low cost monopoly quantity since condition (6) is satisfied with strict inequality. Conditions (1) and (2) are satisfied with strict inequality. The low cost type of incumbent prefers the pooling equilibrium to the Riley equilibrium and the entrant's expected profits are larger in a pooling than in a separating equilibrium.

Moreover, for this parametrization of the model, when there is no asymmetric information between the manager and the owner the undefeatedness criterion chooses the Riley equilibrium, and when there is asymmetric information the undefeatedness criterion excludes all separating equilibria.

5 Conclusion

This papers establishes, in the context of the entry deterrence model of MILGROM and ROBERTS [1982], that entry mistakes can happen because the incumbent practices strategic pricing. An entry mistake may be a Pareto outcome. It is shown that if there is an agency problem between the owner and the manager of the entrant firm there may be pooling sequential equilibria with too much entry that are preferred by both the entrant and the incumbent. This result is surprising because it would be expected that the entrant would prefer to know the type of incumbent in the industry before he takes his decision.

The consequences of using a different equilibrium concept are also explored. The traditional refinements of sequential equilibria that satisfy the stability property of KOHLBERG and MERTENS [1986], like the intuitive criterion, select the Riley equilibrium. More recent refinements that satisfy the undefeatedness property of MAILATH *et al.* [1993], FUJIWARA and POSTLEWAITE [1993], do not select the Riley equilibrium if the low cost type of incumbent prefers some pooling equilibrium to the Riley equilibrium. The Riley outcome is characterized by the fact that although the incumbent firm practices limit pricing, entry would occur in precisely the same circumstances as if the entrant had perfect information about the incumbent's cost. In a pooling equilibrium there is more entry than in a situation where the cost of the incumbent firm is public information.

If in addition it is assumed there is an agency problem between the owner and the manager of the entrant firm four other results are obtained. First, the likelihood of having the lex-max criterion selecting a pooling sequential equilibrium instead of the Riley outcome as the unique equilibrium of the game is higher. Secondly, there will be environments in which a pooling sequential equilibrium which is strictly preferred by both types of incumbent and by the entrant is eliminated by the traditional refinements (which choose the Riley outcome as the equilibrium of the game). Thirdly, the Riley outcome has more limit pricing, the incumbent producing less after entry, the entrant producing more and second period total production higher. Finally, the manager's expected rent is higher in a Riley equilibrium.

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APPENDIX

Some more notation is needed to discuss the elimination of pooling sequential equilibria by the intuitive criterion. Let $V(c_i,y,e) \equiv y(1-\theta_1 c_i - y) + B(c_i,e)$ be the payoff for the incumbent with cost c_i, *i.e.* the sum of period 1's profit and period 2's expected profit, which is a function of the quantity produced in the first period y and the quantity e the entrant is going to produce in the second period. Define the indifference curve for the c_i incumbent, for the equilibrium (y^*,e^*) as, $\beta(c_i,y^*,e^*) = \{(y,e) : V(c_i,y,e) = V(c_i,y^*,e^*)\}$.

We write the slope of the indifference curve β evaluated at (y^*,e^*) as,

$$\frac{de}{dy} = -(\frac{\partial V(c_i,y^*,e^*)}{\partial y})/\frac{\partial V(c_i,y^*,e^*)}{\partial e}.$$

It is easy to verify that $dV/de < 0$, and so the above derivative being strictly positive is equivalent to $1-\theta_1 c_i - 2y > 0$. Since the indifference curve is bell-shaped and symmetric around the shaft $y = (1-\theta_1 c_i)/2$, there is a pair of quantities $\bar{y}(c_i,e)$ and $\underline{y}(c_i,e)$ defined as $\bar{y}(c_i,e) > (1-\theta_1 c_i)/2 > \underline{y}(c_i,e)$, and $V(c_i,e,\underline{y}(c_i,e)) = V(c_i,e,\bar{y}(c_i,e)) = V(c,\bar{e},(1-\theta_1 c_i)/2)$, where $\bar{e}$ is the highest quantity the entrant will ever produce. In any sequential equilibrium the c_i incumbent's expected profit cannot be below the expected profit he receives by choosing $y = (1-\theta_1 c_i)/2$, under the worst conjecture $\bar{e} = e(\mu = 0)$ against him. Thus in any sequential equilibrium the first period quantity chosen by the c_i incumbent must be in the interval $[\bar{y},\underline{y}]$.

A simple computation gives, $\bar{y}(c_i,e) = \frac{(1-\theta_1 c_i)}{2} + \sqrt{B(c_i,e) - B(c_i,\bar{e})}$ and $\underline{y}(c_i,e) = \frac{(1-\theta_1 c_i)}{2} - \sqrt{B(c_i,e) - B(c_i,\bar{e})}$. It is easy to see that $\partial B/\partial e < 0$, which indicates that every type of incumbent has an incentive to signal that he is an efficient producer, and in that way try to convince the entrant to make e small. Furthermore, we obtain $\partial^2 B/\partial e \partial c_i > 0$ which implies that the marginal benefit from changing the belief of the potential entrant is greater for the more efficient incumbent. Using this result we obtain that $\partial \bar{y}/\partial c_i < 0$ and $\partial(\bar{y} - \underline{y})/\partial c_i < 0$. The above equation implies that the bell shaped region for the maximum utility associated with a particular quantity e, gets wider as the incumbent becomes more efficient.

Given any pooling equilibrium with first period quantity y, define y'' to be a first period quantity such that: for $y < \frac{1-\theta_1 c_H}{2}$, y'' is such that $V(c_H,e(\mu = x),y) = V(c_H,e = 0,y'')$ and $y'' > y$, and for $y \geqslant \frac{1-\theta_1 c_H}{2}$, $y'' = y$. There is an $\varepsilon > 0$ such that $y' = y'' + \varepsilon$ and only the low cost type of incumbent is better off if the entrant's belief is $\mu = 1$ when the incumbent produces first period quantity y'. Therefore, the intuitive criterion eliminates all the pooling equilibria.