Entry under an Information-Gathering Monopoly

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Abstract

The effects of information-gathering activities on an entry model with asymmetric information are analyzed. The baseline game is a classical entry game where an incumbent monopoly faces potential entry by one firm without knowing with certainty whether this potential entrant is weak or strong. If the entrant decides to enter, the incumbent must compete with him and decide whether to accommodate or to fight. The paper extends this entry game and considers that the monopoly has access to an Intelligence System (IS) that generates a noisy signal about the entrant's type. We focus on the analysis of the effectiveness of monopoly's action of credibly informing the entrant about her information-gathering activities as an entry deterrence strategy. The results suggest that such an action is effective regardless the precision of the IS only for relatively low entrant's payoff from competing with the incumbent. For higher entrant's payoffs, the effectiveness of this action requires a considerable accurate IS.

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1. Introduction

Information is an important resource for a firm, as much as material, financial and human resources are, because information can make the difference between success and failure. An important part of it is information about other firms (competitors, incumbent firms, potential entrants, etc.), and it can be related to production processes and techniques, costs, efficiency and strength, recipes and formulas, costumer datasets, actions, decisions, plans and strategies, etc.

Competitive intelligence is described as the ethical and legal process of collecting, analyzing and managing information of strategic value about the industry and competitors. This activity can include reviews of newspapers, corporate publications and Web sites, patent filings and specialized databases, among others[1]. However, firms do not always obtain this information ethically and legally. The unethical and illegal process of obtaining information from other firms is called "industrial espionage". Although it is often difficult to discern the legality and ethicality of the methods employed by firms to obtain information about other companies[2], recent advances in communication and information technologies have increased firms' incentives to exceed the limits of competitive intelligence activities and industrial espionage has become a worrying reality (Solan and Yariv, 2004, Barrachina et al., 2014, Zhang, 2014, Kozlovskaya, 2015).

These information-gathering activities may have competitive implications which are particularly important in markets with barriers to entry. Milgrom and Roberts (1982) developed the classical entry game in which the incumbent has private cost information. Sempere-Monerris (1997) has considered that the incumbent is uncertain about an entrant's type who can bring positive demand externalities. Two-sided uncertainty regarding costs is examined by Leblanc (1992). The present paper assumes that the entrant has superior information and the incumbent may counter such a disadvantage by operating an information-gathering technology. Thus, the paper proposes a model that complements our understanding about the role of asymmetric information in settings with strategic interactions.

The recent theoretical analysis of the impact of information-gathering activities on entry deterrence is illustrated by papers such as those of Barrachina et al. (2014, 2015). The former considered the stylized model of entry deterrence by capacity expansion and assumed that the entrant can obtain noisy information about the incumbent's action. The latter carried out a similar analysis but considering the entry game developed by Milgrom and Roberts (1982).

[1] Nasheri (2005). Although these activities are usually carried out by market research firms, many companies have their own competitive intelligence staff (see Billand et al., 2016, and Barrachina et al., 2014).

[2] Crane (2005) is an interesting study of three cases in which competitive intelligence becomes industrial espionage. Perhaps the most curious case is Procter & Gamble attempting to obtain more information about Unilever by hunting through its garbage bins.

However, might an incumbent use information-gathering activities as an entry deterrence strategy?

The goal of the present paper is to develop a theoretical setting that addresses this research question. It elaborates on the previous related work to assume that it is the monopoly (not the potential entrant) who gathers information about the entrant in an attempt to analyze the effectiveness of this information-gathering activity as an entry deterrence strategy.

The paper considers a simple classical entry game where a monopoly incumbent attempts to deter potential entry considering the option of battling the potential entrant (Wilson, 1992). Although it is plausible to assume that the entrant's type (strong or weak) is not known by the monopoly, under symmetric information the monopoly only would fight against a weak entrant, deterring his market entry. In this sense, credibly informing a potential entrant that his level of strength is known, it can be considered as another monopoly's entry deterrence strategy in this context. But might an imperfect knowledge of the entrant's type have a similar effect?

In an attempt to answer this question, the paper extends this entry game assuming that it is commonly known that the incumbent conducts noisy information-gathering activities. It is assumed that the monopoly operates an Intelligence System (IS)[3] to detect the entrant's level of strength. Therefore, if the entrant decides to enter the market, this IS sends out one of two signals. One signal, labeled s, indicates that the entrant is strong, and another signal, labeled w, indicates the opposite (that the entrant is weak). The IS has a precision, meaning that the signal sent by the IS will be correct with a probability equal to this IS precision. Based on the signal received, the incumbent must decide whether (or with what probability) to accommodate or to fight the entrant.

The results obtained suggest that the monopolist's action of credibly informing the entrant about how accurate her information on his type is might have an entry deterrence effect regardless of this accuracy. Actually, that is true when the entrant's payoff for competing with the incumbent is relatively small. Otherwise, the effectiveness of this monopolist's action as an entry deterrence strategy requires a relatively accurate IS, not necessarily perfect but almost perfect when the entrant's payoff from entering the market is considerably high.

As stated above, the paper is related to Barrachina et al. (2014, 2015) and, consequently, to the references therein that theoretically analyzed information-gathering (or information-sharing) activities in general and in an economic context. Moreover, this paper is related, on the one hand, to Begg and Imperato (2001), which analyzed an information-gathering monopoly (as in this paper) that attempted to learn more about uncertain market demand; and on the other hand to the principal-agent literature which considers that the agent can gather information before

[3] Similar to that considered by Solan and Yariv (2004) and Barrachina et al. (2014, 2015).

signing the contract. In the information-gathering models of Su (2017), Terstiege (2016), Crémer et al. (1998a) and Crémer et al. (1998b), among others, the agent's information acquisition can be either strategic (it improves the bargaining position of the agent although it is socially wasteful) or productive (socially useful in terms of production efficiency).

More recent developments in the theoretical analysis of information-gathering activities (not only in an economic context) include Zhang (2014), Kozlovskaya (2015) and Grabiszewski and Minor (2016). Zhang (2014) analyzed information-gathering activities in one-sided contests with private information. As in the present paper, a player conducts information-gathering activities, attempting to obtain information about rival's private knowledge. Although Zhang's (2014) particular framework was not restricted to an economic context, it could be adapted to analyze cases in which a firm attempts to learn more about another firm's strength, as in the present paper, but not in a market entry context. Kozlovskaya (2015) studied a duopoly market in which each competitor conducts information-gathering activities, attempting to obtain its rival's private information about market demand. Although the object of the information-gathering activities in Kozlovskaya (2015) is of the same nature as in the present paper and both papers consider noisy information-gathering technology, their set-ups are different. Finally, Grabiszewski and Minor (2016) analyzed the effectiveness of counterespionage policies considering the interaction between a domestic firm and a foreign firm, in which the former decides to attempt to obtain an innovation, and the latter decides on an information-gathering effort, attempting to copy this innovation and to compete with the former in its commercialization. The information-gathering technology is costly (a counterespionage policy is interpreted as an increase in this cost) but not noisy, and its precision is not observed by the domestic firm.

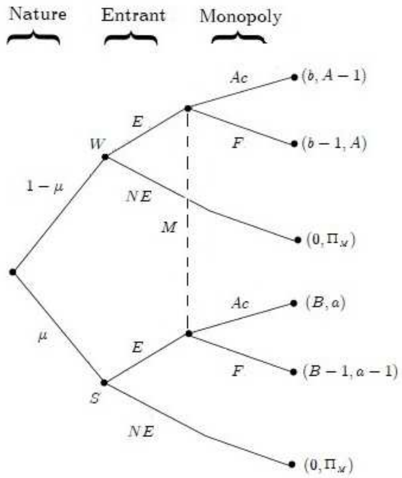
The remainder of the paper is organized as follows. Section 2 establishes the model. The effects of incumbent's commonly known information-gathering activities over market entry are analyzed in Section 3. Section 4 concludes the paper.

2. The Model

The model considers a simple classical entry game where a monopoly incumbent attempts to deter a potential entrant considering the option of battling him (Wilson, 1992). As usually considered in this entry game, the monopoly faces the potential entry without knowing with certainty whether the entrant is weak or strong. Actually, she assigns probability μ that the entrant is strong (in which case he is referred to as having the type S) and $1-\mu$ that he is weak (namely, he is of type W). If the entrant decides not to enter (NE), he obtains zero and the monopoly obtains the monopoly profit (Π_M). However, if the entrant chooses to enter (E), the incumbent must compete with the entrant and decide whether to accommodate (Ac) or fight (F). If the entrant is strong, the monopoly receives a negative payoff ($a-1$) if she decides to fight and a positive one if she decides to accommodate (a). The strong entrant obtains a positive payoff in both cases, but the payoff if the monopoly decides to accommodate is higher ($B > B-1$). If the entrant is weak, the monopoly obtains a positive payoff regardless of whether she decides to fight or accommodate, but the payoff of fighting is higher ($A > A-1$). The weak entrant obtains a positive payoff from entering the market if the monopoly decides to accommodate (b) but a negative one if she decides to fight ($b-1$).

Figure 1 describes this basic situation in extensive form, where $0 < a < 1 < A$ and $0 < b < 1 < B$. Note that the first element in each *2-tuple* of payoffs respresents the payoff for the entrant.

Figure 1. The base game in extensive form



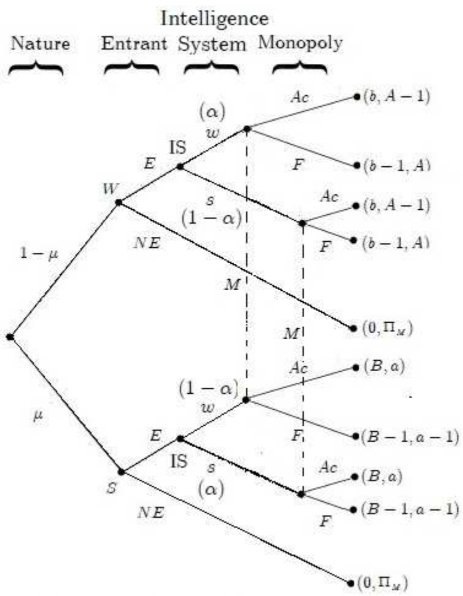
To introduce the monopoly's information-gathering process into the game, let us consider that the monopoly has access to an Intelligence System (IS) that allows her to gather (noisy) information about the entrant's level of strength (namely, whether he is strong or weak). The IS sends one of two signals: the signal s, which indicates that the entrant is strong, and the signal w, which indicates that the entrant is weak. The precision of the IS is assumed to be (without loss of generality) α, $1/2 \le \alpha \le 1$. That is, the signal sent by the IS is correct with probability α (namely, $\Pr(s/S) = \Pr(w/W) = \alpha$ and $\Pr(w/S) = \Pr(s/W) = 1-\alpha$). The case in which $\alpha = 1/2$, that is, when the signal sent by the IS is not informative, is equivalent to the case in which the monopoly does not use any IS (the case depicted in Figure 1). The case $\alpha = 1$ is one in which the IS is perfect (the signal sent by the IS is correct with a probability of 1) and the monopoly knows exactly the type of the entrant, namely we have the symmetric information case. This IS is exactly of the same nature as that considered by Barrachina et al. (2014, 2015) and as the information devices in Solan and Yariv (2004).

We are interested on the effectiveness of the monopolist's action of credibly informing the entrant about how accurate her information on his type is as an entry deterrence strategy. For this reason, the model assumes that the precision of the IS is common knowledge[4]. We also assume that the precision is exogenous (and costless) to analyze the effect of the different possible values of the commonly known precision.

The interaction between the icumbent and the potential entrant is described as a two-stage game of incomplete information $G(\alpha)$. It is analyzed, following Harsanyi's approach, as a three player game, in which the players are the two entrant's types, S and W, and the monopoly. In the first period, the potential entrant chooses between entering the market or not as a function of his type. If he decides not to enter the market, the game ends. But if he enters, the IS sends one of two signals (either s or w) and the monopoly must decide, based on the signal received (from the IS), whether to accommodate or to fight the entrant. The payoffs are the same as the ones considered before.

It is easy to depict this game $G(\alpha)$ by including, in the basic game represented by Figure 1, the IS of precision α operated by the monopoly (note that when $\alpha = 1/2$ the following figure is equivalent to Figure 1).

Figure 2. The game $G(\alpha)$ in extensive form



[4] Note that the model does not consider that the incumbent commits to disclose the precision of the information she obtains. It focuses on the effectiveness of disclosing it as an entry deterrence strategy. As long as the entrant's knowledge of this precision is effective discouraging him from entering the market, the incumbent might be interested in credibly disclosing it. Nevertheless, a complete analysis of incumbent's incentives to discloser should consider the case in which the precision is her private knowledge.

3. Information-Gathering Activity

This section analyzes the effect of the monopoly's commonly known information-gathering activity over market entry. Namely, the effectiveness of monopoly's action of credibly informing the entrant about how accurate the information she obtained about his type is as an entry deterrence strategy.

First of all, it is straightforward to see that to enter is the strictly dominant strategy for the strong entrant regardless of the precision, α, of the IS, since $0 < B-1 < B$ (see Figures 1 and 2). This assumption simplifies the analysis in two ways. On the one hand, under this assumption the most interesting case is that in which, according to her prior beliefs, the incumbent considers it likely that the entrant is weak (namely, $\mu < 1/2$)[5]. On the other hand, this assumption allows us to analyze the effect of information-gathering on market entry considering only the probability that the weak type entrant assigns to E in equilibrium for the different values of α.

As will be shown in the following discussion, b (as a measure of weak entrant payoff from competing with the incumbent) plays an important role in the model as a threshold to assess the precision of the IS and the weak type entrant's decision of entering the market. The main result of the paper is summarized in the following proposition.

Proposition. *Consider the game $G(\alpha)$ for $1/2 \le \alpha \le 1$ and $\mu < 1/2$, and let $Prob_W^E(\alpha)$ be the probability the weak type entrant assigns to E in equilibrium as a function of the precision, α, of the IS. Then $Prob_W^E(\alpha)$ is strictly decreasing in α for $\alpha \in \left[\max(1/2, b), 1\right]$.*

Proof: *See Appendix.*

In fact, the monopoly's action of credibly informing the entrant has an entry deterrence effect regardless of the precision of the IS ($1/2 \le \alpha \le 1$) when the weak entrant's payoff from entering the market is sufficiently low ($b \le 1/2$). Otherwise ($b > 1/2$), it has this effect only for a relatively accurate precision of the IS ($b \le \alpha \le 1$). In this sense, the higher the weak entrant's payoff from entering the market is, the more accurate the IS must be to discourage him from entering the market. In particular, only an almost perfect IS could discourage him when this payoff is considerably high (when b is relatively close to 1).

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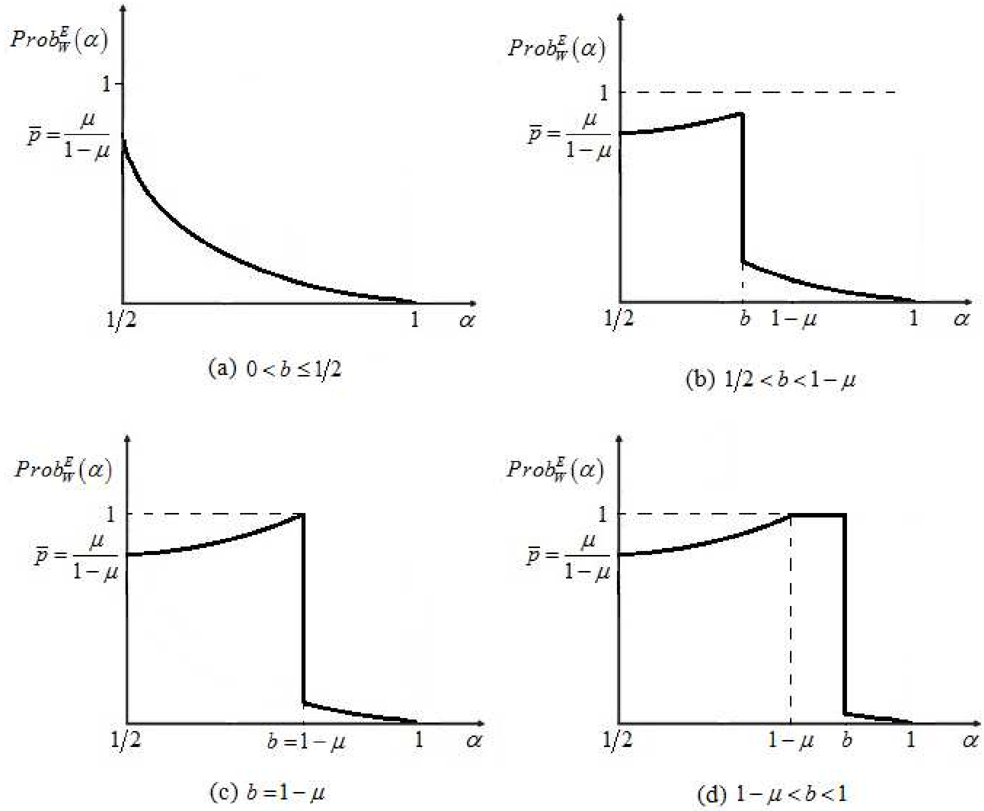
[5] Actually, the conclusion about the effectiveness of monopoly's action of credibly informing the entrant as an entry deterrence strategy when $\mu < 1/2$ is not modified when $\mu \ge 1/2$. Some details will be given in the following discusssion.

The following figure (which can be easily obtained from the results proved in the Appendix) gives more details about the behavior of the probability the weak entrant assigns to enter the market in equilibrium, $Prob_W^E(\alpha)$, depending on the different possible values of b.

Figure 3. $Prob_W^E(\alpha)$ **for the different values of** b **when** $\mu<1/2$



As Figure 3 shows, making a relatively low precision of the IS commonly known may have a procompetitive effect when the weak entrant's payoff from entering the market is sufficiently high. In such a situation, not only may the probability assigned in equilibrium by the weak entrant to enter the market increase with the precision, α, of the IS (see Figure 3 (b), (c) and (d)), but also the weak entrant may decide to enter the market for sure, as shown in Figure 3 (c) and (d)[6].

To analyze these results, consider first the case in which the IS is not informative ($\alpha=1/2$) or equivalently the case in which the monopoly operates no IS (and the entrant knows it), depicted in Figure 1. Note that the monopoly is quite comfortable fighting the entrant considering likely

[6] The incumbent would never be interested in disclosing the precision of the IS when it is not effective as an entry deterrence strategy. However, these results suggest that, in a different setting in which the incumbent operates no IS, the entrant might be interested in sending the incumbent an informative but relatively imperfect and noisy signal about his type (*à la* Crawford and Sobel (1982), for instance), letting her know its accuracy.

he is weak[7]. For this reason the weak entrant does not rule out the option to stay out in an attempt to induce the incumbent to consider the accommodation option[8] (given that to enter and being fought is his worst scenario). Nevertheless, he enters the market with positive probability, in particular $\bar{p} = \mu/(1-\mu)$.

However, when the monopoly receives from the IS an informative but noisy signal about the entrant's type (namely, when $\alpha > 1/2$), the probability the weak entrant can assign to enter the market without discouraging the monopoly from accommodating depends on the signal sent by the IS. In particular, if the monopoly receives the signal s she will not be discouraged from accommodating for a higher range of probabilities of entry than if the signal w is received. Moreover, the more accurate the precision of the IS is, the more the monopoly trusts the signal received and the higher the range of probabilities of entry for which the monopoly will follow the signal sent by the IS (fighting when receiving the signal w and accommodating when the signal s is received).

In this context, the weak entrant could assign a relatively high probability to enter the market (higher than when there is no IS), and increasing with the accuracy of the IS, without discouraging the monopoly from accommodating if she receives the signal s. But in that case he would be assuming the risk of being fought if he is detected, that is, if the monopoly receives the signal w. As shown in Figure 3 (b), (c) and (d), the weak entrant will consider it worthy to take this risk and will enter the market with relatively high probability when his payoff from entering the market and competing with the incumbent is sufficiently high ($b > 1/2$) and, at the same time, the precision of the IS is low enough so he is quite likely not to be detected ($\alpha < b$).

The incumbent will trust completely the signal s, no matter how likely the weak entrant is to enter the market, when the IS is sufficiently accurate (more precisely when $\alpha \geq 1-\mu$)[9]. The weak entrant will take advantage from this situation and will enter the market for sure only when his payoff from entering the market is so high that the precision of the IS can be high enough for the incumbent to trust completely the signal s and, at the same time, not too high so that the weak entrant still considers it worthy to take the risk of being fought[10]. Namely, when $1-\mu \leq \alpha \leq b$ (see Figure 3 (c) and (d)).

[7] Recall that the case $\mu < 1/2$ is being considered.

[8] Note that fighting (not accommodating) is best strategy for the incumbent if she knew the entrant is weak.

[9] This is basically due to the simplifying assumption of the model according to which to enter is the dominant strategy for the strong entrant.

[10] When $\mu \geq 1/2$ the assumption about the strong entrant's dominant strategy implies that the monopoly trusts completely the signal s regardless the precision of the IS. Namely, the weak entrant enters the market for sure even when the IS is quite inaccurate (in the case $\mu > 1/2$ even when $b \leq 1/2$ because the monopoly does not trust the signal

Nevertheless, for a relatively accurate IS ($\alpha > b$) the weak entrant considers he is likely to be detected and it is not worthy for him to take the risk of being fought even though his payoff from entering the market is quite high and the monopoly is not discouraged from accommodating when observing the signal s. In such a situation, he assigns a small probability to enter the market (smaller than when there is no information-gathering activity) to induce the monopoly to consider the accommodation option even when receiving the signal w.

Given that the more accurate the IS is the more the monopoly trusts its signals, the higher the precision of the IS the smaller the range of probabilities of entry the monopoly will accept without fighting when she receives the signal w. Hence, the more accurate the IS is the smaller the probabilty the weak entrant can assign to enter the market without discouraging the monopoly from accommodating when observing the signal w, staying out of the market for sure only when the IS is perfect (see Figure 3 (b), (c) and (d) for $b \le \alpha \le 1$). Namely, only when it is commonly known that the monopoly knows exactly the entrant's level of strength, the weak entrant is completely deterred from entering the market. Otherwise ($1/2 \le \alpha < 1$), under the staying out decision of the weak entrant, the monopoly would have no doubt in accommodating regardless of the signal sent by the IS, making the weak entrant to regret about his decision.[11]

As Figure 3 (a) shows, this anticompetitive effect of the commonly known information-gathering activity of the monopoly is always the case (regardless of the accuracy of the IS) when the weak entrant's payoff from entering the market is quite small ($b \le 1/2$) so that he does not consider worthy to take the risk of being fought even when he is unlikely to be detected[12].

4. Summary and Conclusions

Firms usually gather information relative to other firms. Although these firms' information-gathering activities may have competitive effects, which can be especially important in markets

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w for low values of the precision of the IS, more specifically for $\alpha < \mu$). However, this inaccurate IS makes no difference over the weak entrant's decision of entering the market. Note that, even in the case in which the monopoly operates no information-gathering activity, she is not completely discouraged form accommodating regardless of the decision of the weak entrant, so the weak entrant decides to enter the market for sure.

[11] This anticompetitive effect is the same when $\mu \ge 1/2$, although when $\mu > 1/2$ and $b \le \mu$ this decrease in the probability assigned by the weak entrant to enter the market starts when the monopoly starts trusting the signal w, namely when $\alpha > \mu$.

[12] This is the same when $\mu = 1/2$. However, when $\mu > 1/2$ a relatively inaccurate IS has no effect on weak entrant's decision of entering the market for sure even when $0 < b \le \mu$. This is due to the fact that the incumbent does not trust the signal w when it is correct only with a relatively low probability (more precisely when $\alpha < \mu$) since not only does she consider likely the entrant to be strong according to her prior beliefs, but also to enter is the strong entrant's dominant strategy.

with barriers to entry, little theoretical work has been undertaken to analyze them. This paper takes a modest step forward in closing this gap in the literature by considering a model in which a monopoly incumbent does not know the level of strength (strong or weak) of a potential entrant and uses an Intelligence System (IS), of a certain precision, that sends noisy signals about this level of strength. If the entrant finally decides to enter the market, the monopoly uses this information to decide whether to accommodate or to fight the entrant.

The paper has considered a simplified version of this entry deterrence model in which if the entrant is strong, he is always willing to enter the market regardless of the accuracy of the information-gathering activity. In this sense, the paper has focused on the most interesting case in which according to her priors beliefs, the incumbent considers it likely the entrant is weak.

In such a setting, when it is common knowledge that the monopoly is conducting no information-gathering activity, a weak entrant does not rule out the option of staying out of the market. Nevertheless, when it is common knowledge that the monopoly knows exactly the entrant's level of strength, a weak entrant stays out for sure because the monopoly would battle him otherwise. In this sense, it might seem that credibly informing the entrant about how accurate the knowledge obtained by the monopoly about his type is has an entry deterrence effect (and it can be considered a complementary entry deterrence strategy for the monopoly in this context), regardless of the accuracy of this knowledge.

Nevertheless, it is shown that a commonly known informative (but imperfect) information-gathering activity based on noisy signals conducted by the incumbent may have either procompetitive or anticompetitive effects, depending on both the precision of the IS and the entrant's payoff from entering the market. In particular, a relatively low precision of the IS might have a procompetitive effect because the entrant considers it likely that the monopoly could be confused by the IS and he is not going to be detected. However, this is only true if the entrant's payoff from entering and competing with the incumbent is sufficiently high for him to consider worthy to take the risk of being detected. In this context, only a relatively accurate precision of the IS (not necessarily perfect but the more accurate the higher the payoff from entering the market) would discourage the entrant from entering the market. Nevertheless, if the payoff from entering the market is so low that the entrant does not consider it worthy to take the risk of being detected even for low precisions of the IS, the commonly known information-gathering activity has an entry deterrence effect regardless of its accuracy.

If the cases in which, according to incumbent's prior beliefs, she does not consider a weak entrant more likely than a strong one were considered, it would be observed that the commonly known information-gathering activity either has the same entry deterrence effect, or a relatively inaccurate IS makes no difference over market entry.

All these results suggest that the monopoly's action of credibly informing the entrant about her information-gathering activity would not be always effective as an entry deterrence strategy. It would be effective regardless of the precision of the information obtained by the monopoly only when the entrant's payoff from competing with the incumbent is relatively low. For a higher entrant's payoff, the entry deterrence effectiveness of this action would require considerable accurate information.

Appendix

The present Appendix proves the Proposition and the behavior of the probability the W-type entrant assigns to E in equilibrium, $Prob_W^E(\alpha)$, depicted in Figure 3 in the main text.

First, as stated in the main text, E is the S-type entrant's dominant strategy in $G(\alpha)$ for all $\alpha \in [1/2, 1]$ because $0 < B-1 < B$ (see Figures 1 and 2 in the main text). Let $\Pr(E/t)$ be the probability assigned to E by the t-type entrant. Hence, $\Pr(E/S)=1$ in every possible equilibrium of $G(\alpha)$ for all $\alpha \in [1/2, 1]$.

Next, the following analysis focuses on the equilibrium strategies of the W-type entrant in $G(\alpha)$ for $1/2 \leq \alpha \leq 1$ and $\mu < 1/2$. Consider first the two extreme cases $\alpha = 1/2$ and $\alpha = 1$. The following lemma summarizes the equilibrium strategies of the W-type entrant in these two cases.

Lemma A1. *Consider the game* $G(\alpha)$ *for* $0 < \mu < 1/2$. *Then,*

(1) if $\alpha = 1/2$, *the* W *-type entrant assigns in equilibrium probability* $\bar{p} = \mu/(1-\mu)$ *to enter the market;*

(2) if $\alpha = 1$, *the* W *-type entrant stays out in the unique equilibrium of the game.*

<u>Proof:</u>

(1) Note that the game $G(\alpha)$ when $\alpha = 1/2$ is equivalent to the game despicted in Figure 1 in the main text in which it is common knowledge that the monopoly operates no IS.

First, the expression for the monopoly's updated beliefs is obtained. Applying Bayes' rule, the probability that the monopoly assigns the entrant is of type $t = \{S, W\}$, given that she observes a market entry (the entrant chose E) is

$$\Pr(t/E) = \frac{\Pr(E/t)\Pr(t)}{\sum_{t=S,W} \Pr(E/t)\Pr(t)} \qquad \text{(A1)}$$

where $\Pr(t)$ is the prior probability the monopoly assigns to the t-type entrant, namely $\Pr(S) = \mu$ and $\Pr(W) = 1-\mu$.

The monopoly's expected payoffs for choosing F and Ac can be calculated applying the expression for her updated beliefs given by (A1). These two expected payoffs are given by

$$EU_M(F) = \Pr(S/E)(a-1) + \Pr(W/E)A \tag{A2}$$

$$EU_M(Ac) = \Pr(S/E)a + \Pr(W/E)(A-1) \tag{A3}$$

Assume next that the W-type entrant assigns to E a certain probability $p \in [0,1]$, namely $\Pr(E/W) = p$. From (A1),

$$\Pr(S/E) = \frac{\mu}{\mu + p(1-\mu)} \tag{A4}$$

$$\Pr(W/E) = \frac{p(1-\mu)}{\mu + p(1-\mu)} \tag{A5}$$

Further, substituting (A4) and (A5) in (A2) and (A3),

$$EU_M(F) = \frac{\mu(a-1) + p(1-\mu)A}{\mu + p(1-\mu)} \tag{A6}$$

$$EU_M(Ac) = \frac{\mu a + p(1-\mu)(A-1)}{\mu + p(1-\mu)} \tag{A7}$$

Note that (A6) is equal to (A7), and the monopoly is indifferent between F and Ac only if the W-type entrant chooses to enter the market with probability $p = \bar{p}$, where $\bar{p} = \mu/(1-\mu)$ and $\bar{p} \in (0,1)$ since $0 < \mu < 1/2$.

Hence, if the W-type entrant assigns probability $\bar{p}$ to E, the monopoly will choose F with a certain positive probability $\beta \in (0,1)$ when observing a market entry. The W-type entrant will not deviate from the mixed strategy $(\bar{p}, 1-\bar{p})$ only if he is indifferent between his two pure strategies, E and NE. Specifically, $\beta(b-1) + (1-\beta)b = 0$, and this semi-pooling equilibrium exists if the monopoly chooses to fight the entrant with probability $\bar{\beta} = b$, where $0 < b < 1$.

If the W-type entrant assigns probability $0 \le p < \bar{p}$ to E, (A6) is smaller than (A7), namely, the monopoly accommodates if she observes a market entry, and the W-type entrant has incentives to deviate to choosing E purely. Similarly, if the W-type entrant assigns probability $\bar{p} < p \le 1$ to E, (A6) is higher than (A7), which implies that the monopoly fights if she observes a market entry and the W-type entrant has incentives to deviate and choose NE purely.

(2) When $\alpha = 1$, namely the IS is perfect, M can detect perfectly the entrant's type and $G(\alpha)$ becomes a game of complete information. Since it is common knowledge that M knows the entrant's type and she will choose her action based on it (Ac if the entrant is strong and F if the entrant is weak), the weak entrant does not enter the market because $b - 1 < 0$.

■

Consider next the intermediate cases in which $1/2 < \alpha < 1$. Before analyzing the equilibrium strategies of the W -type entrant, let $\bar{q}(\alpha) = \mu(1-\alpha)/\alpha(1-\mu)$ and $\tilde{q}(\alpha) = \alpha\mu/(1-\alpha)(1-\mu)$ be two threshold probabilities assessing the monopoly's decision of accommodating or fighting depending on the probability assigned by the W -type entrant to enter the market. The following lemma summarizes important features of these two threshold probabilities.

Lemma A2. *Consider the threshold probabilities* $\bar{q}(\alpha)$ *and* $\tilde{q}(\alpha)$.

(1) $0 < \bar{q}(\alpha) < \tilde{q}(\alpha)$ *for every precision,* α *, of the IS,* $\alpha \in (1/2,1)$ *;*

(2) $\bar{q}(\alpha) < 1$ *for all* $\mu \in (0,1/2)$ *and* $\tilde{q}(\alpha) < 1$ *iff* $\alpha < 1-\mu$ *;*

(3) $\bar{q}(\alpha)$ *decreases with the precision,* α *, of the IS, while* $\tilde{q}(\alpha)$ *increases;*

(4) both $\bar{q}(\alpha)$ *and* $\tilde{q}(\alpha)$ *are convex (relative to* α *); and*

(5) $\bar{q}(1/2) = \tilde{q}(1/2) = \mu/(1-\mu)$ *;* $\bar{q}(1) = 0$ *, and* $\tilde{q}(1)$ *is not well defined (but* $\tilde{q}(\alpha)$ *approaches infinity as* α *approaches 1).*

Proof:

(1) It is straight forward to see that $\bar{q}(\alpha) > 0$ and $\tilde{q}(\alpha) > 0$ for all $\mu \in (0,1/2)$ and $\alpha \in (1/2,1)$. It is also easy to see that $\bar{q}(\alpha) < \tilde{q}(\alpha)$ for all $\alpha > 1/2$.

(2) $\bar{q}(\alpha) < 1$ iff $\mu(1-\alpha) < \alpha(1-\mu)$, which is always satisfied since $\mu < 1/2 < \alpha$. $\tilde{q}(\alpha) < 1$ iff $\alpha\mu < (1-\alpha)(1-\mu)$, which is straight forward to see that it is equivalent to $\alpha < 1-\mu$.

(3) $\partial\bar{q}(\alpha)/\partial\alpha = -\mu(1-\mu)/\left(\alpha(1-\mu)\right)^2 < 0$ for all $\alpha \in (1/2,1)$ because $\mu \in (0,1)$; and $\partial\tilde{q}(\alpha)/\partial\alpha = \mu(1-\mu)/\left((1-\alpha)(1-\mu)\right)^2 > 0$ for all $\alpha \in (1/2,1)$.

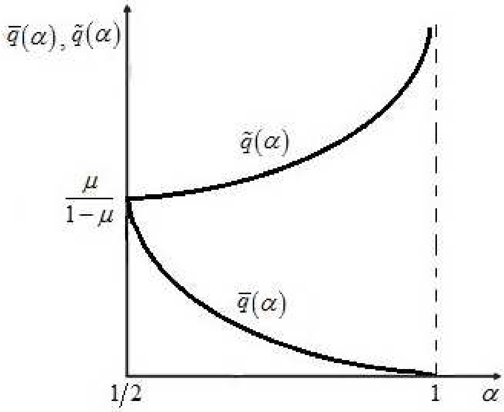
(4) $\partial^2\bar{q}(\alpha)/\partial\alpha^2 = 2\mu(1-\mu)^2/\left(\alpha(1-\mu)\right)^3 > 0$ and $\partial^2\tilde{q}(\alpha)/\partial\alpha^2 = 2\mu(1-\mu)^2/\left((1-\alpha)(1-\mu)\right)^3 > 0$ for all $\alpha \in (1/2,1)$.

(5) Straight forward.

■

It is useful to draw $\bar{q}(\alpha)$ and $\tilde{q}(\alpha)$ according to their features in Lemma A2.

Figure 4. $\bar{q}(\alpha)$ **and** $\tilde{q}(\alpha)$



The following lemma summarizes the equilibrium strategies of the W -type entrant in $G(\alpha)$ for $1/2<\alpha<1$.

Lemma A3. *Consider the game* $G(\alpha)$ *for* $1/2<\alpha<1$ and $\mu<1/2$. *Then,*

(1) when $1/2<\alpha<1-\mu$, *the equilibrium strategy of the* W *-type entrant depends on* α *and* b*: if* $\alpha<b$, *the* W *-type entrant enters the market with probability* $\tilde{q}(\alpha)$*; if* $\alpha=b$, *the game has a multiplicity of equilibria in which the* W *-type entrant enters the market with probability* $q\in\left[\bar{q}(\alpha),\tilde{q}(\alpha)\right]$*; and if* $\alpha>b$, *the* W *-type entrant assigns probability* $\bar{q}(\alpha)$ *to enter the market;*

(2) when $\alpha=1-\mu$, *the equilibrium strategy of the* W *-type entrant depends on* b*: if* $b<1-\mu$, *the* W *-type entrant enters the market with probability* $\bar{q}(\alpha)$*; if* $b=1-\mu$, *the game has a multiplicity of equilibria in which the* W *-type entrant enters the market with probability* $q\in\left[\bar{q}(\alpha),1\right]$*; and if* $b>1-\mu$, *the* W *-type entrant enters the market for sure; and*

(3) when $1-\mu<\alpha<1$, *the equilibrium strategy of the* W *-type entrant depends on* α *and* b*: if* $\alpha<b$, *the* W *-type entrant enters the market for sure; if* $\alpha=b$, *the game has a multiplicity of equilibria in which the* W *-type entrant enters the market with probability* $q\in\left[\bar{q}(\alpha),1\right]$*; and if* $\alpha>b$, *the* W *-type entrant enters the market with probability* $\bar{q}(\alpha)$.

<u>Proof:</u>

In $G(\alpha)$ for $1/2<\alpha<1$ the expression for the monopoly's updated beliefs when she observes a market entry and the signal $\sigma=\{s,w\}$ sent by the IS are obtained applying Bayes' rule and are given by

$$\Pr\left(t/E,\sigma\right)=\frac{\Pr\left(E,\sigma/t\right)\Pr\left(t\right)}{\sum_{t=S,W}\Pr\left(E,\sigma/t\right)\Pr\left(t\right)}$$

Equivalently,

$$\Pr(t/E,\sigma)=\frac{\Pr(E/t)\Pr(\sigma/t)\Pr(t)}{\sum_{t=S,W}\Pr(E/t)\Pr(\sigma/t)\Pr(t)} \tag{A8}$$

where $\Pr(\sigma/t)$ is the probability that the IS sends the signal σ given that the entrant is of type t. In particular, $\Pr(s/S)=\Pr(w/W)=\alpha$ and $\Pr(w/S)=\Pr(s/W)=1-\alpha$ as considered in the main text.

Let $EU_M(F/\sigma)$ and $EU_M(Ac/\sigma)$ be the monopoly's expected payoffs for choosing F and Ac respectively when she observes a market entry and the IS sends the signal σ, which can be obtained applying (A8),

$$EU_M(F/\sigma)=\Pr(S/E,\sigma)(a-1)+\Pr(W/E,\sigma)A \tag{A9}$$

$$EU_M(Ac/\sigma)=\Pr(S/E,\sigma)a+\Pr(W/E,\sigma)(A-1) \tag{A10}$$

Consider next that the W-type entrant assigns probability $q\in[0,1]$ to E, namely $\Pr(E/W)=q$. From (A8),

$$\Pr(S/E,s)=\frac{\alpha\mu}{\alpha\mu+q(1-\alpha)(1-\mu)} \tag{A11}$$

$$\Pr(W/E,s)=\frac{q(1-\alpha)(1-\mu)}{\alpha\mu+q(1-\alpha)(1-\mu)} \tag{A12}$$

$$\Pr(S/E,w)=\frac{(1-\alpha)\mu}{(1-\alpha)\mu+q\alpha(1-\mu)} \tag{A13}$$

$$\Pr(W/E,w)=\frac{q\alpha(1-\mu)}{(1-\alpha)\mu+q\alpha(1-\mu)} \tag{A14}$$

Substituting (A11) and (A12) in (A9) and (A10), the monopoly's expected payoffs when observing the signal s are obtained,

$$EU_M(F/s)=\frac{\alpha\mu(a-1)+q(1-\alpha)(1-\mu)A}{\alpha\mu+q(1-\alpha)(1-\mu)} \tag{A15}$$

$$EU_M(Ac/s)=\frac{\alpha\mu a+q(1-\alpha)(1-\mu)(A-1)}{\alpha\mu+q(1-\alpha)(1-\mu)} \tag{A16}$$

Note that (A15) is strictly higher than (A16) and consequently the monopoly will choose F when observing the signal s only if $q>\tilde{q}(\alpha)$.

The monopoly's expected payoffs when observing the signal w are obtained substituting (A13) and (A14) in (A9) and (A10),

$$EU_M(F/w)=\frac{(1-\alpha)\mu(a-1)+q\alpha(1-\mu)A}{(1-\alpha)\mu+q\alpha(1-\mu)} \tag{A17}$$

$$EU_M\left(Ac/w\right)=\frac{(1-\alpha)\mu a+q\alpha(1-\mu)(A-1)}{(1-\alpha)\mu+q\alpha(1-\mu)} \tag{A18}$$

The monopoly will choose F when observing the signal w, namely (A17) is strictly higher than (A18) only if $q>\bar{q}(\alpha)$.

As stated by the first and second parts of Lemma A2, $\bar{q}(\alpha)<\tilde{q}(\alpha)$ and $\bar{q}(\alpha)<1$ for all $\mu\in(0,1/2)$ and $\alpha\in(1/2,1)$.

The proof of Lemma A3 follows from considering the following cases.

Case 1. Consider the case where $\alpha\in(1/2,1-\mu)$. In this case, according to the second part of Lemma A2, $\tilde{q}(\alpha)<1$. If in this case the W-type entrant assigns to E a probability $q\in\left[0,\bar{q}(\alpha)\right)$, (A15) is strictly smaller than (A16) and (A17) is strictly smaller than (A18). Namely, the monopoly will choose Ac irrespective of the signal sent by the IS and the W-type entrant is better off deviating and choosing E purely. If in this case the W-type entrant assigns to E a probability $q\in\left(\tilde{q}(\alpha),1\right]$, (A15) is strictly higher than (A16) and (A17) is strictly higher than (A18). Namely, the monopoly will choose F irrespective of the signal sent by the IS and the W-type entrant is better off deviating and choosing NE.

If in this case the W-type entrant assigns to E a probability $q=\bar{q}(\alpha)$, (A15) is strictly smaller than (A16) but (A17) is equal to (A18). Namely, the monopoly will choose Ac when observing the signal s and, being indifferent between F and Ac when observing the signal w, will assign some probability $\gamma\in[0,1]$ to F. The W-type entrant, knowing that if he enters the market the IS sends the right signal w with probability α (and the wrong signal s with probability $1-\alpha$), will not deviate from the mixed strategy only if he is indifferent between his two pure strategies. Namely,

$$(1-\alpha)b+\alpha\left(\gamma(b-1)+(1-\gamma)b\right)=0$$

Equivalently, $\gamma=\bar{\gamma}$, where $\bar{\gamma}=b/\alpha$.

Considering that $\bar{\gamma}\le 1$ if $\alpha\ge b$, and the case $\alpha\in(1/2,1-\mu)$ is being analyzed, this semi-pooling equilibrium always exists when $b\le 1/2$, and when $1/2<b<1-\mu$ it exists only if $\alpha\ge b$. When $b\ge 1-\mu$, this semi-pooling equilibrium does not exist because $\alpha<b$ always.

If in this case the W-type entrant assigns to E a probability $q\in\left(\bar{q}(\alpha),\tilde{q}(\alpha)\right)$, (A15) is strictly smaller than (A16) but (A17) is strictly higher than (A18). Namely, the monopoly will choose Ac when observing the signal s and F when observing the signal w. The W-type entrant will not deviate from the mixed strategy only if

$$(1-\alpha)b+\alpha(b-1)=0$$

Equivalently, $\alpha = b$.

Considering that the case $\alpha \in (1/2, 1-\mu)$ is being analyzed, this semi-pooling equilibrium only exists when $1/2 < b < 1-\mu$.

If in this case the W -type entrant assigns to E a probability $q = \tilde{q}(\alpha)$, (A15) is equal to (A16) but (A17) is strictly higher than (A18). Namely, the monopoly being indifferent between F and Ac when observing the signal s will assign some probability $\lambda \in [0,1]$ to F , and will choose F when observing the signal w . The W -type entrant will not deviate from the mixed strategy only if

$$(1-\alpha)\left(\lambda(b-1)+(1-\lambda)b\right)+\alpha(b-1)=0$$

Equivalently, $\lambda = \bar{\lambda}$, where $\bar{\lambda} = (b-\alpha)/(1-\alpha)$.

Note that $\bar{\lambda} < 1$ always because $b < 1$ but $\bar{\lambda} \geq 0$ only if $\alpha \leq b$. Considering that the case $\alpha \in (1/2, 1-\mu)$ is being analyzed, this semi-pooling equilibrium does not exist when $b \leq 1/2$ because $\alpha > b$ always in that case. When $1/2 < b < 1-\mu$ this semi-pooling equilibrium exists only if $\alpha \leq b$; and when $b \geq 1-\mu$ this semi-pooling equilibrium always exists.

Case 2. Consider the case where $\alpha \in [1-\mu, 1)$. In this case, according to Lemma A2, $\tilde{q}(\alpha) \geq 1$.

Similar to the previous case, there is no equilibrium in which the W -type entrant assigns to E a probability $q \in \left[0, \bar{q}(\alpha)\right)$. If the W -type entrant assigns to E a probability $q = \bar{q}(\alpha)$, as explained in the previous case, the semi-pooling equilibrium exists only if the monopoly chooses F with a probability of $\bar{\gamma}$. However, considering that in this case $\alpha \in [1-\mu, 1)$ and $\bar{\gamma} \leq 1$ if $\alpha \geq b$, this semi-pooling equilibrium always exists when $b \leq 1-\mu$. When $b > 1-\mu$, this semi-pooling equilibrium exists only if $\alpha \geq b$.

If in this case the W -type entrant assigns to E a probability $q \in \left(\bar{q}(\alpha), 1\right)$, as similarly explained in the previous case, the monopoly will choose Ac when observing the signal s and F when observing the signal w and the semi-pooling equilibrium exists only if $\alpha = b$. However, considering that the case $\alpha \in [1-\mu, 1)$ is being analyzed, this semi-pooling equilibrium exists when $b = 1-\mu = \alpha$ or when $b > 1-\mu$ and $\alpha \in (1-\mu, 1)$, otherwise $\alpha > b$ and the W -type entrant will have incentives to deviate.

Finally, consider the case in which the W -type entrant chooses E purely (namely, assigns to E a probability $q = 1$). Two subcases must be considered here.

Subcase 2.1. Consider the case where $\alpha = 1-\mu$. In this case, according to Lemma A2, $\tilde{q}(\alpha) = 1$.

Hence, if the W -type entrant assigns to E a probability $q = 1$, $\bar{q}(\alpha) < q = \tilde{q}(\alpha)$. Namely, the monopoly is indifferent between F and Ac when observing the signal s and assigns to F some probability $\lambda \in [0,1]$, but chooses F for sure when observing the signal w. The W-type entrant will not deviate from E only if

$$(1-\alpha)\left(\lambda(b-1)+(1-\lambda)b\right)+\alpha(b-1)\geq 0$$

Equivalently, $\lambda \leq \bar{\lambda}$.

Considering that $\bar{\lambda} \geq 0$ if $\alpha \leq b$ and the case $\alpha = 1-\mu$ is being analyzed, this pooling equilibrium only exists when $b \geq 1-\mu$ (otherwise $\bar{\lambda} < 0$ because $\alpha = 1-\mu > b$).

Subcase 2.1. Consider the case where $\alpha > 1-\mu$. In this case, according to Lemma A2, $\tilde{q}(\alpha) > 1$. Hence, if the W-type entrant assigns to E a probability $q = 1$, $\bar{q}(\alpha) < q < \tilde{q}(\alpha)$. Namely, the monopoly will choose Ac when observing the signal s and F when observing the signal w. The W-type entrant will not deviate form E only if

$$(1-\alpha)b+\alpha(b-1)\geq 0$$

Equivalently, $\alpha \leq b$.

Considering that the case $\alpha > 1-\mu$ is being analyzed, this pooling equilibrium only exists when $b > 1-\mu$ (otherwise $\alpha > b$ always and the W-type entrant will have incentives to deviate).

■

The proof of the Proposition and Figure 3 in the main text follows immediately from Lemmata A1-A3.

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