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## Information Acquisition and Entry\*

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## Abstract

Before firms decide whether to enter a new market or not, they have the opportunity to buy information about several variables that might affect the profitability of this market. Our model differs from the existing literature on endogenous information acquisition in two respects: (1) there is uncertainty about more than one variable, and (2) information is acquired secretly. When the cost of acquiring information is small, entry decisions will be as if there was perfect information. Equilibria where each firm acquires only a small amount of information are more robust than the socially undesirable equilibria where all firms gather all information. Examples illustrate the importance of assumptions (1) and (2).

# 1 Introduction

Consider the decision of a firm whether or not to enter a market. Especially in the case of a new market firms face uncertainty about the market conditions and other factors that affect the potential profits from entry. For example, firms might be uncertain about demand and costs of production. More specifically, the production costs may be considered to be the aggregate of several partial costs, such as the costs of labour, material, distribution and advertising. Similarly, demand for the product may be determined by factors as fashion, the weather and the state of the economy. Of course, the entry decision that *ex ante* maximizes expected payoff need not maximize the payoff *ex post*. That is, firms would behave differently if they had more information and would achieve higher expected payoffs. Firms thus have an incentive to acquire information, but the usual models do not allow for that possibility. In the real world, however, firms often do have the opportunity to gather information, for example by hiring the services of a consulting agency. Firms could then make their entry decision contingent on the information they receive from this agency.

Information acquisition has been studied extensively in the economics literature before. This literature has, however, two important shortcomings. First, it is assumed that there is uncertainty about one parameter only. As argued before there may be uncertainty about several parameters, especially in the context of an entry model. Aggregating uncertainties about several parameters into a single one is artificial. In order to reduce uncertainty firms will have to acquire information about the underlying parameters (*e.g.* demand or cost). Those parameters should, therefore, be part of the model. If multidimensional uncertainty is considered, there is the possibility that firms "specialise" in obtaining information of a particular nature. That is, they can differentiate themselves endogenously. This particular feature of our model does not appear in models of one-dimensional uncertainty.

A second shortcoming of the existing literature is that it usually assumes that information cannot be acquired secretly. Information acquisition is modeled as a two stage game. When one firm engages in the acquisition of information in the first stage (say about demand), this activity is observed by the other firms. Although this does not mean that they can learn the content of the information (i.e. whether demand is low or high), they do learn the type of information. Subsequent decisions in the second stage may therefore depend on these observations. In our opinion, excluding the possibility of obtaining some information secretly (that is, without being observed) goes beyond

reality.

In this paper we model information acquisition therefore as a one stage game. Firms face uncertainty about several stochastic variables that influence the profitability of the market. Firms can learn the outcome of each variable by investing some resources in research. Each firm has to decide about which variables it wants to be informed. After having obtained this information firms have to decide whether to enter or not.

These plausible assumptions yield intuitively appealing results. First, when costs of information gathering are small, entry decisions are *as if* firms had perfect information about the state of the world. This does not necessarily mean that all firms gather all information. It does imply, however, that lack of information cannot cause too much or too little entry. When information costs are higher inefficiencies of this type may occur.

Second, we show that when information costs are small, there are multiple equilibria that exhibit the "as if"-behaviour. In some of these equilibria firms specialize. That is, each firm becomes informed about one variable only, with different firms becoming informed about different variables. In other equilibria all firms learn about all variables. These equilibria are socially undesirable because many firms do the same research and lots of time and money are wasted. The socially desirable equilibrium (the one where firms specialize) is robust to several variations and perturbations of the model whereas the undesirable equilibrium is not. The specialization equilibrium is feasible for a wider range of information cost parameters, complexity constraints cannot destroy it, and firms have no incentives to "free ride" on other firms' research efforts.

Although all these results are very intuitive, they do not hold when information acquisition is modeled as a two stage game. It is shown that even if information is very cheap, lack of information can cause inefficiencies. Moreover, in a two stage game firms can credibly threaten not to use the information. We also show that when information about one particular variable is cheap, it may happen that no firm will learn about it and that, consequently, inefficiencies may arise. This is caused by the multidimensionality of uncertainty. It is, therefore, important to model multidimensional uncertainty explicitly and one should not aggregate all uncertainty into one single economic indicator.

As mentioned before, endogenous information acquisition has received some attention in the past. Mostly it is modeled as a two stage game, where information is acquired in the first stage. Second period decisions can be conditioned on the type of information acquired by all firms. The only exception we are aware of is Matthews' (1984) auction game, where the participants can acquire some information about the object that is for sale before they submit their bids. The participants cannot observe whether the

others are gathering information or not. Chang and Lee (1992), Hwang (1993, 1995), Li *et al.* (1987), Ockenfels (1989), Ponssard (1979) and Vives (1988) consider models of quantity competition with uncertainty about demand. Before quantities are chosen simultaneously in the second stage, there is a stage in which the firms can buy information in the form of obtaining a signal correlated with the true demand. The firms can choose the precision of the signal, with higher precisions requiring more expenditures.<sup>1</sup> It is assumed that at the beginning of the second stage the precisions chosen in the first stage are commonly known. That is, it is assumed that each firm observes the precision of information of his opponents before it makes its decision about quantity, and the quantity choice may therefore depend on these precisions. Daughety and Reinganum (1992) consider a timing game. Information acquisition can endogenously generate a signaling game. Milgrom (1981) considers auctions as in Matthews (1984). Here bids may depend on the number of participants that chose to become informed.

A model of entry with multidimensional uncertainty was also analyzed by Fershtman and Kalai (1993). They study the behaviour of an incumbent firm that is active in several markets. In each of these markets there is uncertainty about demand. A firm can learn the true demand and, therefore, be able to respond to fluctuations in demand in some markets. The incumbent faces complexity constraints and is unable to be flexible in all markets. Learning about demand in at most  $k$  markets is free while learning about more markets is prohibitively costly. It is shown that this constraint forces firms to concentrate their attention on few markets, and that it can serve to deter entry.

The rest of the paper is organized in the following way. In the next section we introduce the formal model of (secret) information acquisition in an entry game. We state and prove the propositions about the limiting case when costs of information tend to zero. In section 3 we characterize the structure of equilibria when information costs are small. Section 4 gives a detailed example of two firms facing uncertainty about two variables. We compare our results with those of a two stage game in section 5. Section 6 concludes.

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<sup>1</sup>In Chang and Lee (1992), Hwang (1993, 1995) and Vives (1988) precision is chosen from a continuum. In Ockenfels (1989) and Ponssard (1979) the choice of precision is a binary one: Firms either learn the true demand perfectly or they do not learn anything. Li *et al.* (1987) considers both the continuum and discrete approximations of it.

## 2 The Model

There are  $n$  symmetric firms that have to decide whether to enter a market. The profitability of this market depends on the state of the world,  $\omega$ , which in turn depends on  $N$  different parameters  $x_1, \dots, x_N$ . Each parameter  $x_i$  is the outcome of a discrete random variable  $X_i$  and can take two values, *Good* or *Bad*. We let  $K = 2^N$  denote the number of states and denote by  $\rho : \Omega \rightarrow (0, 1]$  the probability distribution over the states of the world induced by the random variables  $X_i$ . We do not exclude the possibility that the variables are correlated, but we impose that each state of the world occurs with positive probability. Now every state corresponds to an entry game  $g(\omega) = (A, u^\omega)$ , where  $A_i = \{e, d\} \forall i$ . If a firm chooses the action  $d$  (do not enter) he will receive a profit of zero. The profit of a firm that chooses  $e$  (enter) depends on the state of the world  $\omega$  and on the number of firms that also enter. The profits increase when parameters change from *Bad* to *Good*, and are decreasing in the number of firms that choose to enter. For each  $\omega$  there exists a unique number  $0 \leq k(\omega) \leq n$  such that if  $k(\omega)$  or less firms enter they will make a strictly positive profit, and if more choose to enter they will make a loss. These assumptions imply that the pure equilibria of  $g(\omega)$  are those strategy profiles where exactly  $k(\omega)$  firms enter. Firms are symmetric, so any subset of  $k(\omega)$  firms can enter.

The above payoff structure can be justified by assuming that after entry firms compete in quantities à la Cournot. Suppose that after entry, which may have taken a considerable amount of time (to build a plant for example), all uncertainty will be resolved. That is, the firms that entered know the state of the world and they know how many competitors there are. The payoffs of  $g(\omega)$  represent the equilibrium payoffs of this Cournot competition.

A firm can learn for any of the variables whether the realization is *Good* or *Bad*. It will have to decide for which variables it wants to learn the realization. Suppose it chooses to be informed about the variables in some subset  $I \subset \{X_1, \dots, X_N\}$ . If two states  $\omega$  and  $\omega'$  differ only with respect to variables not included in  $I$ , then it has to choose the same action in those states. Therefore, a strategy for firm  $j$  in the meta game  $\Gamma$  is a pair  $(I_j, s_j)$ , where  $I_j$  denotes the set of variables to be informed about and where  $s_j : \Omega \rightarrow \{e, d\}$  is such that  $s_j(\omega) = s_j(\omega')$  whenever  $\omega$  and  $\omega'$  differ only with respect to variables not included in  $I_j$ .

The payoff in the meta game is the expected payoff in  $g(\omega)$  over all  $\omega \in \Omega$  minus the cost of acquiring information,  $c(I_j)$ . We assume that  $c(\emptyset) = 0$  and that  $I \subset I'$

implies that  $c(I') > c(I)$ . That is, learning about more variables is more expensive. Information about one variable may be more expensive than information about another. Note that, since acquiring information is costly and is done secretly, it is a strictly dominated strategy to choose to learn about a variable but never use the information. In an equilibrium strictly dominated strategies are never used. It will be convenient to write  $s_j^*$  for the strategy  $(I_j, s_j)$ , where  $s_j^*(\omega) = s_j(\omega)$  for all  $\omega \in \Omega$ , and where  $I_j$  is the smallest set that provides sufficient information to play  $s$ .

Of course, the equilibria of  $\Gamma$  will depend on the costs of information gathering. In particular, if costs are prohibitively large, no player will gather any information. Firms will either enter or not. In a pure equilibrium of  $\Gamma$  there will be some fixed number of firms that enter. However, in some states  $\omega$  this number will be greater than the optimal number of entrants,  $k(\omega)$ . In other states  $\omega'$  this number will be smaller than  $k(\omega')$ . Information costs then act as a barrier to entry. For intermediate values of the information cost, firms will not gather all information. Consequently too little or too much entry could occur also in this case. The next proposition, however, shows that this cannot happen if information costs are very small.

**Proposition 1** Fix  $\Omega$  and  $g(\omega)$ . Let  $\Gamma^c$  denote a meta game in which learning about all variables costs  $c > 0$ . Let  $s_c^*$  be a pure equilibrium of  $\Gamma^c$ . Then, if the limit exists,  $\lim_{c \rightarrow 0} s_c^*(\omega)$  is an equilibrium of  $g(\omega)$  for all  $\omega \in \Omega$ .

**Proof.** Suppose on the contrary that there exist a state  $\omega'$  and a player who is not choosing the optimal action in this state in the limit. For small information costs this remains true. This player can profitably deviate by choosing to learn about all variables (which is cheap) and then choose the optimal action in case the true state is  $\omega'$ . This contradicts the presumption that  $s_c^*$  is an equilibrium of  $g(\omega)$ .  $\square$

Proposition 1 says that if information costs are very small, in each of the states of the world the players will act *as if* the state of the world was known to all. This does not imply that all firms actually know the state of the world. In the following section we will show that this behaviour can be sustained even when firms gather very small amounts of information. The proposition only holds if information about *all* variables is cheap. One might think that if information about a certain variable is cheap, there will be at least one firm that will choose to learn about it. This intuition, however, turns out to

be wrong as we show by means of an example in section 4.

Proposition 1 shows that an equilibrium of the meta game implies equilibrium in all entry games, if information costs are small. The opposite also holds, *i.e.* any combination of pure equilibria of the entry games constitutes an equilibrium of the meta game.

**Proposition 2** For all  $\omega \in \Omega$  let  $s(\omega)$  denote a pure Nash equilibrium of  $g(\omega)$ . Let  $\Gamma^c$  denote a meta game in which learning about all variables costs  $c > 0$ . Then there exists an equilibrium  $s_c^*$  of  $\Gamma^c$  such that  $\lim_{c \rightarrow 0} s_c^*(\omega) = s(\omega)$  for all  $\omega \in \Omega$ .

**Proof.** Simply define  $s_c^*(\omega) = s(\omega)$  for all  $\omega$ . That is, each firm  $j$  learns the minimal amount of information that allows it to play in each state  $\omega$  the same action as  $s_j(\omega)$ .  $\square$

**Remark:** The discussion thus far has been restricted to pure strategies. From the proof of proposition 1 it can easily be seen that it can be extended to mixed strategy equilibria. That is, any mixed strategy equilibrium of the meta game implies (in the limit) equilibrium in each entry game. It is not so clear whether proposition 2 can be generalized to mixed strategy equilibria as well. In any case, the proof of such a claim should be considerably different than the proof for pure strategies. Namely, learning the minimal amount of information to be able to play a mixed equilibrium of the entry game will often mean that all information has to be acquired. (Because the probabilities used in the mixed strategy equilibria generally differ from state to state.) Notice that in a mixed strategy equilibrium of any entry game firms make zero profits. So learning all information and always playing the mixed equilibrium is dominated by always staying out.

### 3 Information Structures

Consider an entry game with  $n$  firms, and  $n$  variables, which are either *Good* or *Bad*. We assume that in each of the  $\binom{n}{k}$  states where exactly  $k$  variables are *Good*, there is room for exactly  $k$  firms to enter. That is, in the pure equilibria of the corresponding game  $k$  firms enter. If costs of information are small, proposition 1 tells us that in a pure equilibrium of the meta game, exactly  $k$  firms will enter in these states. However, the proposition does not tell us anything about what information will be acquired. We now take a closer look at the information structures that might prevail.

There are many information structures that will support the behaviour predicted by



proposition 1. Namely, let  $\gamma$  be a correspondence that assigns to each state  $\omega$  a subset of firms  $F$ , such that the number of *Good* variables determining  $\omega$  equals the cardinality of  $F$ .<sup>2</sup> Now  $\gamma$  corresponds to an equilibrium of the game in which firm  $i$  learns the minimal amount of information that allows it to enter in state  $\omega$  if and only if  $i \in \gamma(\omega)$ . Learning about all variables will give sufficient information, but there may be cheaper ways to implement the above strategy.

Let us consider two "extreme" examples. First, consider the following strategy for firm  $i$ : Learn the outcome of all variables and enter if and only if at least  $i$  variables are *Good*. It is easy to verify that these strategies form an equilibrium of the meta game (which we will denote by  $s^{ineff}$ ) when the costs of becoming informed are sufficiently low. Profits differ from firm to firm. Each firm has to incur the maximal information cost. Firm 1 enters always, except when all variables are *Bad*. Firm  $n$ , however, only enters when all variables are *Good*. To sustain this equilibrium the cost of acquiring all information must be less than the expected profit made by the firm that enters only if all variables are *Good*. This means that information costs must be very low.

Next, consider the following strategy for firm  $i$ : Learn the outcome of the  $i$ -th variable and enter if and only if it is *Good*. It is easy to verify that these strategies form an equilibrium,  $s^{eff}$ , when the information costs are low. Each firm enters in  $2^{n-1}$  states of the world while only one variable has to be learned. On the other hand, each firm has to learn about at least one variable in order to have all firms enter when all variables are *Good* and no firm entering when all variables are *Bad*. So gross profits are relatively high while information costs are at a minimum.

We see that when information costs are small, many equilibria exist which differ with respect to the total amount of money spent on research. They also differ with respect to the degree of "shared" knowledge, that is the number of variables that are commonly learned by several firms. When we now increase the information costs gradually, the equilibria where all firms learn everything will disappear. In particular,  $s^{ineff}$ , the equilibrium in which one of the firms learns everything but enters only if all states are *Good*, is the first to disappear. On the other hand,  $s^{eff}$ , where each firm learns about one variable and enters in half of the states, will be the last to disappear. Hence, the equilibria where firms "specialize" in obtaining information about a particular variable are more robust to increases in information costs.

Above we assumed that firms can, in principle, decide to obtain as much information

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<sup>2</sup>Note that the number of such correspondences equals  $\prod_{k=0}^n \binom{n}{k}$ .

as possible by hiring more external market research companies. However, if a firm cannot use the services of external agencies and has to use its own research utilities, then the size of its research unit imposes an exogenous limit on the number of variables it can learn. If that limit is smaller than  $n$ , then  $s^{ineff}$  is no longer an equilibrium of the meta-game. Of course,  $s^{eff}$  will remain an equilibrium as long as firms can do some research. This exogenous limit on the amount of information firms can get is similar to Fershtman and Kalai's (1993) model of bounded complexity. In their model, bounded complexity may lead firms to focus their efforts on some markets and to withdraw from others. In terms of our model of information costs, bounded complexity represents the case where learning about up to some fixed amount of variables is free, and learning about any additional variable is very expensive.

We have argued that  $s^{eff}$  is robust to increasing information costs and to complexity restrictions. We now show that it is robust against an additional perturbation of the model. Suppose that firms do not always choose their strategies simultaneously. A firm can wait and observe the behaviour of the other firms. Without being too formal we observe that  $s^{ineff}$  cannot be an equilibrium outcome of this game. This is because the firm that is only supposed to enter when all states are *Good* could "free ride" on the other firms. When it observes that some other firms did not enter, it can infer that not all states are *Good*. In this case it will decide to stay out without having to spend resources on research. Only in case all other firms entered, it may have to do some research. On the other hand,  $s^{eff}$  will be an equilibrium outcome of this perturbed game. Firms have no incentive to wait in this case because the information obtained by one firm is of no use to any of the other firms. We conclude that equilibria where all firms spend a lot of time and money on research are subject to the risk of "free riding" and therefore are unlikely to appear.

## 4 Two Firms

The discussion thus far has been restricted to the case where information costs are very small. In this section we remove this restriction. We assume that there are only two firms and that only the two (aggregate) variables cost and demand influence the profitability of the market. For a particular specification of the payoffs we will analyze the equilibria in detail as a function of the cost of obtaining the different types of information. Here we model information acquisition as a one stage game, that is, entry decision cannot be made contingent on other firms' information gathering decisions. In the next section

we will use the same example when we compare the one stage game with the two stage game.

Two firms have to decide whether to enter a market. The profitability of this market depends on two parameters, cost and demand, which are not known to the firms at the time they have to decide on entry. Both parameters can only take two values. Demand (cost) is high with probability one half. For convenience, let us assume that the two parameters are independent. The profit for each firm also depends on whether or not the other firm enters. The profits are given in Figure 1.

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Figure 1.

If demand is high, there is room for both firms to operate profitably, independent of whether the cost is high or low. Even if the other firm decides to enter, it is optimal to enter. Profits are higher when costs are low. However, if demand is low, there is no room for both firms to enter. In fact, when costs are low this market is a natural monopoly and profits can be made only if one firm enters. In case the costs are high, the market is very bad and no profits can be made. In this case no firm wants to enter.

Learning the true value of cost (resp. demand) costs  $c$  (resp.  $d$ ). We assume for convenience that finding out about both costs simply  $c + d$ . There is obviously a trade-off between becoming better informed and the cost of gathering the information by hiring

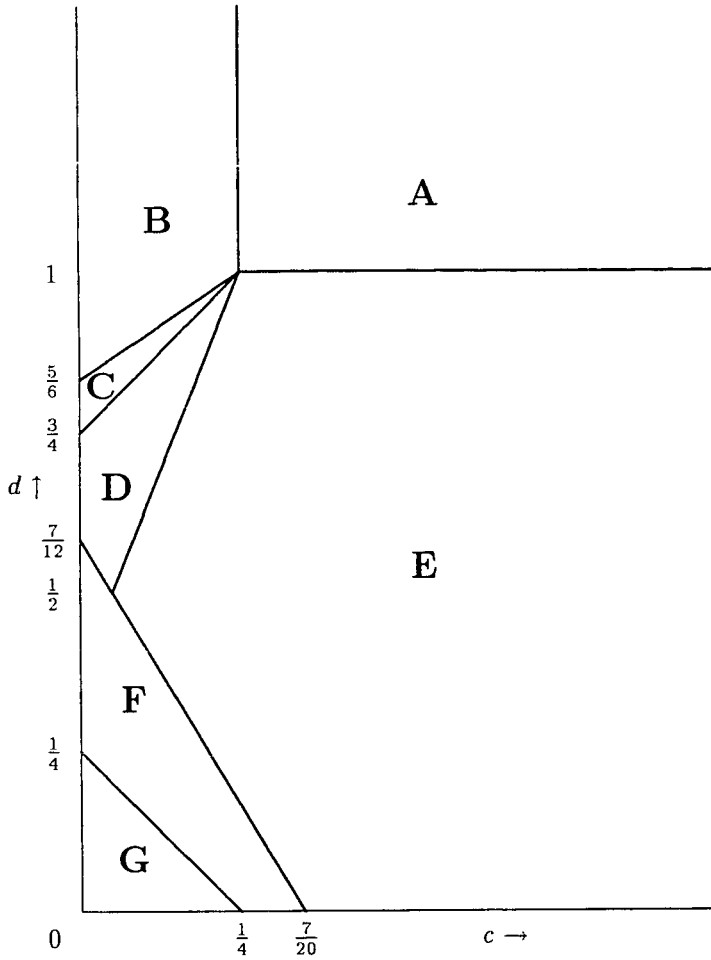


Figure 3: Equilibria of the Meta Game

A:  $(eeee, eeee)$

B:  $(eeee, eded)$ ,  $(eded, eeee)$  and mixed equilibrium with support  $\{eeee, eded\}$

C:  $(eeee, eded)$ ,  $(eded, eeee)$  and mixed equilibrium with support  $\{eeee, eded, eeed\}$

D:  $(eeee, eedd)$ ,  $(eedd, eeee)$  and mixed equilibrium with support  $\{eeee, eded, eeed\}$

E:  $(eeee, eedd)$ ,  $(eedd, eeee)$  and mixed equilibrium with support  $\{eeee, eedd\}$

F:  $(eeee, eedd)$ ,  $(eedd, eeee)$  and mixed equilibrium with support  $\{eeee, eedd, eeed\}$

G:  $(eed, eedd)$ ,  $(eedd, eeed)$  and mixed equilibrium with support  $\{eedd, eeed\}$

There are some interesting observations to make. First, apart from the equilibrium in area A, where information costs are so high that acquiring any information is not sensible, all pure equilibria are asymmetric: The two firms choose to obtain different information. The mixed equilibria are symmetric, but since firms randomize in these equilibria, it

may occur that they end up doing different things. Note that the probabilities that are used in the mixed strategy equilibria may depend on  $c$  and  $d$  and therefore vary within each of the areas. Consider for example a mixed equilibrium in the interior of area G. In equilibrium firms choose  $eedd$  with probability  $(1 + 4c)/3$  and  $eedd$  with probability  $(2 - 4c)/3$ . When firms use these strategies they will enter in states  $\omega_1$  and  $\omega_2$  and stay out in state  $\omega_4$ . In state  $\omega_3$  each firm will enter with probability  $(1 + 4c)/3$ . In the limit as  $c$  tends to zero, this probability goes to  $1/3$ , which is exactly the probability of entry in the mixed equilibrium of  $g(\omega_3)$ . (Compare proposition 1.) The mixed equilibrium outcome of  $g(\omega_3)$  can thus be obtained as the limit of equilibria of the meta game as  $c$  goes to zero. Note, however, firms randomize between learning and not learning about costs. If they learn that costs are low they will enter for sure. Firms will never deliberately randomize between entering and not entering. (Compare proposition 2 and the remark following it.)

Second, we see from the above results that there is often too much entry, that is, more firms are entering than when there would be perfect information about cost and demand parameters. Also too little entry may occur. For example, in the pure equilibria in areas B and C only one firm enters if the true state is  $\omega_2$ . This illustrates that information costs may serve as a barrier to entry. When information about a certain variable is expensive, firms do not learn about it and play an "average" game instead. The payoffs in this game depend on the probabilities of *Good* and *Bad* states. If firms are "optimistic", *i.e.* they believe that the *Good* state will occur with high probability, then we will have too much entry in case this variable happens to be *Bad*. Similarly, if firms are "pessimistic" there exist states with too few entrants.

Finally, consider the part of area F where the costs for learning about production costs are close to zero. In the pure equilibria, however, no firm will choose to learn about costs. The firm that learns about demand cannot gain from learning costs, given the fact that the other firm will always enter. The other firm could gain from learning about costs, because it could prevent entry in the worst state of the world,  $\omega_4$ . But then the firm also needs to know about demand, otherwise entry in the profitable state  $\omega_2$  is impossible. Learning about demand, however, is quite costly.

This example shows the importance of having uncertainty about more than one variable. If there was only uncertainty about cost, and it was very cheap to get informed, then (according to proposition 1) firms would choose to become informed such that they would act as if there was perfect information. Hence, at least one firm should learn the outcome of this variable. However, the presence of uncertainty about an additional

variable (demand), which is quite costly to learn, destroys the argument and as a result nobody will get informed about cost. The vast majority of models so far investigated the case of one-dimensional uncertainty. Our example shows that results that hold in a world of one-dimensional uncertainty, might not hold in a world where uncertainty exists about more than one variable.

## 5 Observable Information Acquisition

Above we have considered the information acquisition and entry game as a one-stage game. Firms condition their entry decision only on their (privately obtained) information. As we remarked in the introduction, the existing literature on endogenous information acquisition assumes that information acquisition decisions are observed and considers therefore a two-stage game. In this section we examine the two-stage version of the game analyzed above. In the first stage firms simultaneously decide about which variables to be informed. Before firms take their decision in the second stage, they are not only informed about the variables chosen, but they also know about which variables their competitors are informed. In this model, each firm can make its entry decision, therefore, contingent on the other firm's information acquisition decision.

Each firm has four actions in the first stage: become informed about cost, demand, both or neither. We denote these actions by  $C$ ,  $D$ ,  $C&D$  and  $\emptyset$ , respectively. The second stage has therefore 16 starting points. We will insist that at each of these starting points a continuation equilibrium is played. Formally this means that we take sequential equilibrium as the relevant solution concept.<sup>4</sup> For some choices of variables in the first stage there exists a unique continuation equilibrium. For example, in case neither firm learns anything entering is a dominant strategy in the second stage. For some other choices of variables, however, multiple continuation equilibria exist. For example, after the choice of  $(C&D, D)$ , firms can continue in three ways: (1) firm 1 enters unless demand is low and cost is high, firm 2 enters if demand is high; (2) firm 1 enters if demand is high, firm 2 enters in any case; (3) both firms mix between the strategies used in (1) and (2). Note that the second equilibrium is somewhat peculiar, since firms do not seem to use their information completely. For instance, learning about demand and entering in any state is a dominated strategy in the one stage model. But here it is a credible threat in order to deter the other firm from becoming fully informed.

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<sup>4</sup>Since the move of Nature precedes the moves of the players, there are not many proper subgames. Subgame perfection does not have much bite here.

The diagram in Figure 4 lists all continuation equilibria and the corresponding payoffs (excluding the information costs).

|                | <i>C&amp;D</i>                                       | <i>C</i>  | <i>D</i>  | $\emptyset$       |
|----------------|--|---|---|-------------------|
| <i>C&amp;D</i> | eed,eedd 7/4,5/4<br>eedd,eed 5/4,7/4<br>mix 5/4,5/4  |   | eed,eedd 7/4,5/4<br>eedd,eeee 5/4,6/4<br>mix 5/4,5/4  | eedd,eeee 5/4,6/4 |
| <i>C</i>       |  | eded,eeee 2/4,4/4<br>eeee,eded 4/4,2/4<br>mix 2/4,2/4 |   | eded,eeee 2/4,4/4 |
| <i>D</i>       | eedd,eed 5/4,7/4<br>eeee,eedd 6/4,5/4<br>mix 5/4,5/4 | eedd,eeee 5/4,6/4                                     | eeee,eedd 6/4,5/4<br>eedd,eeee 5/4,6/4<br>mix 5/4,5/4 | eedd,eeee 5/4,6/4 |
| $\emptyset$    | eeee,eedd 6/4,5/4                                    | eeee,eded 4/4,2/4                                     | eeee,eedd 6/4,5/4                                     | eeee,eeee 1/4,1/4 |

Figure 4.

Now suppose that the costs of acquiring information are small but positive. Consider the strategy profile where firm 1 learns about both variables and where firm 2 learns about demand and where they then continue with playing (*eed,eedd*). This was the equilibrium outcome of the one stage game. But it is obvious that this is not an equilibrium outcome here. Firm 2 can deviate and choose (commit) to not obtain any information. In that case player 1 has to revise his second period strategy, because firm 2 will enter in any case. Therefore it will then choose to enter only if demand is high, and not use its information about costs.

From this diagram it can be easily read that, if the information costs are small but positive, there is essentially a unique pure strategy equilibrium outcome: One firm learns nothing, the other firm learns about demand. To sustain this as an equilibrium outcome, however, firms have to continue with the equilibrium (*eedd,eeee*) in case the non-learning firm deviates and chooses to become completely informed.

This example clearly shows how perverse the effects can be of assuming that entry decisions can be made contingent on the information acquisition of other firms. Propositions 1 and 2 need not hold in such a context. Hence, even if the costs of acquiring

information become very small, inefficiencies (in this case entry in non-profitable markets) arise because of the lack of information. Moreover, in the two-stage game firms can credibly threaten not to use their private information. In our opinion this demonstrates that information acquisition is better modeled by a one stage game than by a two stage game.

## 6 Conclusions

We analyzed endogenous information acquisition in the setting of an entry game. In contrast to the existing literature and more in accordance with reality, we assumed that information is acquired secretly. Moreover, we allowed for uncertainty about more than one variable. If information is cheap, firms will buy all the information they need. Lack of information cannot be the cause of inefficiencies in the sense of too much or too little entry. Other types of inefficiencies may arise, however. Some equilibria exhibit socially undesirable amounts of time and money wasted on market research. We showed, however, that these inefficient equilibria are vulnerable with respect to increasing information costs, complexity constraints and free riding.

We find our results intuitive. What is striking, however, is that they do not hold under the assumptions usually made in the literature. For example, if information acquisition is assumed to be observable, firms may gather insufficient information. A firm that is known to be very well informed may namely provoke aggressive behaviour of the other entrants.

We have modeled multidimensional uncertainty explicitly. We find that representing all uncertainty by one single parameter is artificial. In order to reduce uncertainty firms have to gather data about real variables as cost and demand. One can hardly imagine what it means to gather information about an abstract economic indicator. Still, one might think that analyzing models of one-dimensional uncertainty yields also insights in models of multidimensional uncertainty. As we have shown, however, such partial analysis may yield qualitatively different results.

In this paper we have focussed on entry games. We believe that the above considerations are valid for a wider range of information acquisition models. The plausibility of the assumptions used in these models can be questioned. The robustness of their results needs to be examined carefully.



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