INFORMATION ACQUISITION
BY FIRMS
AND
MARKET STRUCTURE

by
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B.A. in Economics, Marmara University, 1994

Submitted to the Institute for Graduate Studies
in Social Sciences in partial fulfillment of the
requirements for the degree of

Master
of
Arts

Marmara University

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To my family,
and
the memory of
my Grandfather

Acknowledgments

Throughout this study, I received substantial assistance from my teachers and friends. In particular, I would like to thank my supervisor, Professor Fatma Doğruel, for her great encouragement to the study on this topic. Her criticism were very useful for me.

I also appreciate the support and help of my teacher, Professor Ercan Eren. I would like to thank to him for his advices.

I would like to thank the members of the Department of Economics of Yildiz Technical University.

Last, but not least, I appreciate the strong support from my family.

ABSTRACT

The goal of this study is to investigate the relationship between information and market structure. The study uses the Bayesian learning (updating) technique to show the influences of the incomplete information among the firms in a market structure, especially, in the different types of duopoly.

One finding is that the marginal costs of the firms play an important role in all processes of information that are acquired. In the acquisition of information process, marginal cost structure of the firms determine the amount of the information that they acquire. In the different market structure, the firms that are oligopolist, competitive or monopolist behave with the help of the convexity of the marginal cost function. Also, marginal cost is not only one factor which affects the acquisition of information but it has very crucial role to determine the influences of incomplete information in the market structure.

The interesting results is about the conflict between sharing information activities of the firms and the anti-trust authorities behavior. The literature, generally supports that the firms have to share their private information eachother but in the real world, anti-trust authorities take the positions for penaltying or removing such a behavior among firms.

CONTENTS

1. INTRODUCTION

In recent years, there has been a growing interest in studying explicitly the role of information in economic situations. This interest has brought a growing literature together. The information concept is, usually, met in microeconomic textbook. The most popular one is that buyers and sellers have full information about markets that they interested. This is an assumption of Neoclassical school. In the stage of the development of the new schools in economics, this assumption change from the full information to incomplete information.

On that point, individuals have incomplete information and there is an asymmetry about information that they have. Also, this is related to that agents do not make same decisions on the similar state of nature for any economic problem. That aspect makes the economist solve the problems of agent under uncertainty with incomplete information. Due to the assumption of classical school about information, the economics as a science is very utopic. Either this criticism or the development of new economic theory is a way to go to the reality. On the other hand, the important role of information on our real life requires to study information as a commodity.

The information concept was studied as a differentiated commodity, public good and normal good. If we look at the information on the structure perspective, then we can easily see the changing meaning of the information concept because the consumption of the private information maximizes the utility of the consumer like a normal good but gives to the other agents disutility. In microeconomic theory, the way to study on that problem is in two subsection which is consumer theory or firm theory. In that work, I study the influence of incomplete information among firms. The main purposes of the study is to explain the role and use of information in economic theory and the role and use of information in firm theory.

Section 2 deals the role and use information in economic theory such as economic behavior and information or games with incomplete information. Section 3 concentrates the role and the use of information in microeconomic theory such as value of it or sharing of it by firms. Section 4 contains the conclusion remark and some future aspect of information with new technological tools such as *Internet* as a new communication channels to give message among agents in order to provide information.

2. INFORMATION IN ECONOMIC THEORY

2.1. General Perspective

A clear understanding of the concept of information is a necessary prerequisite for any discussion of economic topics. Information theory usually circumvents the problem by defining major concepts only with reference to the technical aspects of signal transmission. For these purely physical processes, information theory can be worked out as a branch of probability theory.[1] To grasp the crucial role information processing in social systems this is completely inadequate. In economics, game theory has become the most important tool in economic theory to model more sophisticated information environments.[2]

The idea of the following models is to capture information processes in an even broader sense than usually done in economic theory. Information is not only considered as a `commodity`, acquired at a certain cost and yielding a certain additional revenue such that increasing marginal cost and decreasing marginal revenue determine optimal information processing. Indeed this type of model is only concerned with what Hanappi (1994) would call "optimal information consumption". Another strand of economic theory goes a little bit further and discusses information as a typical public good: Once it is there, everybody is glad to use it, but there is no incentive for any single participant in the game to initiate its production.[3]

Information is central to all applied studies in economics. It has many facets. As empirical data, it provides the basis for testing economic model or theory. It is also intimately connected with decision making under conditions of risk and uncertainty. Hence the choice of optimal policy under an uncertain environment depends on the type of information structure

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[1] There are another approaches to the information theory in economics such as non-expected utility approach.

[2] Game Theory sometimes restricts the purpose of the researcher but information environment is generated most popularly in that theory.

[3] The production of information has very crucial aspect on the economic theory. Like in the Game Theory, in the economics of information usually do not interest in the production process of information.

e.g. is partial or total, incomplete or complete, imprecise or precise and symmetric or asymmetric. (Sengupta, 1993).

In communication theory in engineering the central problem is to analyze the process of information transmission through a noisy channel. A channel is the link between the source which sends a certain message coded before transmission and the destination where the message is decoded. Due to the presence of the noise, which represents any kind of distorting influence which is random in its effect, the information passing through a channel gets randomly distorted or modified. The theory of information transmission in noisy channels seeks to analyze the implications of different statistical laws applying to the information source and the probabilities of the different types of distortion introduced by the channel.[4]

The economics of information looks at the demand for and value of both public and private information as it affects the behavior of the agents in the market. Thus at the micro level the economics of information analyzes the implication of asymmetric information structures e.g. the seller may complete information on the product it sells, while the buyers may have incomplete information, since the search process is costly. Another implication is the asymmetric information among firms about uncertain demand or cost function. One firm have complete information, while another have incomplete information. At the macro level one may analyze e.g. the concept of informational efficiency of the capital market e.g. the what extent a security market is informational efficient in the sense of its prices fully reflecting all available information? or what is the role of the market information signals in the formation and change of the equilibrium price vector in a market where the traders are rational economic agents in a competitive framework? Clearly, at the micro level, we will analyze the role of information in a market, when it is related to uncertain demand function.

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4 Information transmission by channels is very old concept but in the Network Economics or the logical structure of the Internet is the same.

The economist's view of information has primarily focused on the specification problem and the decision making problem. At the specification stage the economist raises two broad issues (1) what is the informational role of prices as signals which link the two sides of market equilibrium i.e. demand and supply? Since the model of competitive equilibrium requires that all market information is freely available to the agents, one needs to characterize the informational aspects of such markets. Models of rational expectation discuss this aspect in terms of the theory of expectations and the equilibrating role of markets; (2) what is the most appropriate measure of income or welfare distribution, when different income classes are involved? Measures of social indicators or quality of life raise similar issues. Since parametric measures of income inequality which depend on a few parameters such as mean and variance, may be sensitive to data variations, nonparametric measures which depend on ranks or distances have been increasingly applied.[5] (Sengupta, 1993).

Making optimal decisions under conditions of uncertainty has provided the second major focus for the economist in his concern for information. Since the economist is rarely capable of duplicating information as in a laboratory experiment by a physicist or chemist, he has the need to develop decision rules that are optimal in some broad sense even when there is incomplete information. The distinction between complete vs. incomplete information thus plays a very important role in economic decision models. Typical example of incomplete information is as follow: a duopoly game where one supplier does not know the demand function of the market or supply function of his competitor or his cost function. Lack of complete knowledge about the random state of nature has been pervasive characteristic of most applied decision models in economics.

A second important distinction in forms of information structures is between perfect

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[5] This subject is related to econometrics of information which has a widespread literature in econometrics.

vs. imperfect information which arises very naturally in game theory. The distinction is that the players in a strategic game have imperfect information when there is some uncertainty about actual behavior of the players till a new decision made. Thus in markets with imperfect information the potential buyers are badly informed about sellers' prices.

A third important distinction in information structures in economic models is between adaptive and non-adaptive information. Adaptive or sequential information arises primarily in dynamic models, where the decision-maker has the opportunity to learn from the past realizations of the dynamic system. Learning or adaptivity can take several forms e.g. (1) through a flexible model which provides continuous information about the state of system and its performance, (2) through the design of robust policies which are capable of estimating the unknown information during the system's information, (3) through building elements of caution and risk aversion in the optimal decision rule. Thus the feedforward control rules allow forecast values of the futures states to influence the current decisions, just as the feedback rules allow the past to influence the present control policies. Since dynamic models are more applicable to intertemporal decision situations, the adaptive information structure is more suitable in dynamic frameworks. For example, dynamic portfolio models with time-varying risk aversion posses some features of adaptivity. Macroeconomic policy models emphasizing stabilization and growth also need to have flexibility and risk-sensitivity built into the design of optimal policy.

Now, on the next section, the entropy, uncertainty and information relationship will be shown in order to give the logarithmic information definition. This approach is the beginning point for the communication channels and the value of information.

2.2. Information, Entropy and Uncertainty

Many problems in the social sciences concern the division of some given total into a number of components. The question may then arise: How large is the degree of dividedness? The entropy provides an answer to this question. A state of nature in probabilistic terms that defines the uncertainty needs how much information acquisition in order to do state of nature certainly.

Also, uncertainty prevails prior to the message and information is received when the message arrives. The more uncertainty prior to message, the larger is the amount of information conveyed by it, at least on the average. Therefore, the entropy originally introduced here as the expected information of the messages that states which of the *n* possible outcomes is realized, may also be regarded as a measure of the uncertainty associated with a distribution whose probabilities are $p_1, ..., p_n$.[1]

Let consider an event *E* with probability *p*; the nature of the event is irrelevant. At some point in time we receive a reliable message stating that *E* in fact occurred. The question is: How should one measure of the amount of information conveyed by the message?

We shall answer it in an intuitive manner. Suppose that *p* is close to 1 (e.g. p=.95). Then, one may argue, the message conveys very little information, because it was virtually certain that *E* would take place. But suppose that p=.01, so that it is almost certain *E* will not occur. If *E* nevertheless does occur, the message stating this will be unexpected and hence contains a great of information.

These intuitive ideas suggest that, if we want to measure the information received from

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[1] In this regard it is comparable with the variance (or the standard variation) of a random variable whose values are real numbers; such a variance, too, is a measure of the uncertainty of the outcome. The main difference is that the entropy can and the variance cannot be applied to nominal variables: those which take "qualitative" rather than quantitative values, such as black and white, or Catholic, Protestant, and Jew, or current assets and fixed assets on a balance sheet. This is so because the entropy in contrast to the variance depends exclusively on the probabilities with which these possible outcomes are realized, not on the (numerical or nonnumerical) values of these outcomes. (Theil, 1972)

a message in terms of probability p that prevailed prior to the arrival of the message, we should select a decreasing function. The function is

$$h(p)=\log 1/p=-\log p \qquad (1)$$

which decreases from to 0 (zero information when p is one). The function is illustrated Figure 1.1.

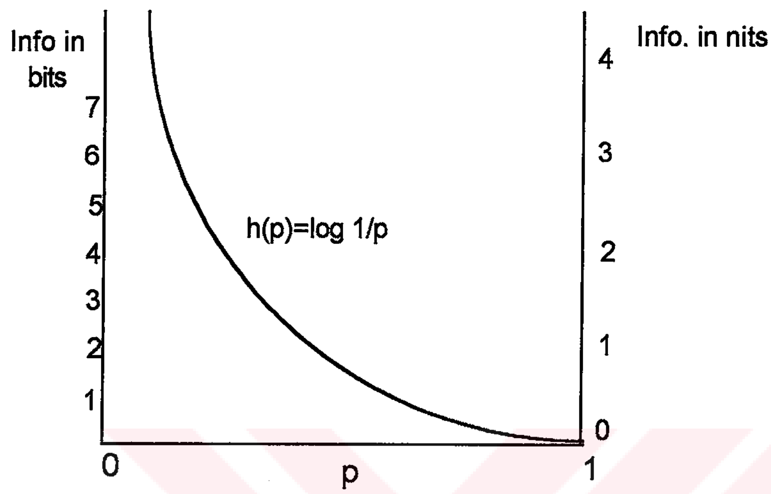

Figure 1.1 Information measured in nits and bits

Information is said to be measured in binary digit or for short, bits when it is used as a base in logarithm. When natural logarithms is used, the information unit is nits.

The objective of this section is to show that the logarithmic information definition, also in equation (1), is the only possible definition when certain simple axioms are accepted.

The axioms are all concerned with the information content of a reliable message which states that event E occurred, given that the probability of E prior to the message was p. Axiom I states that this information depends only on p. Hence it can be written as $h(p)$, but this function is not, of course, of the specific logarithmic form (1) at this stage. Axiom II states that $h(p)$ is a continuous function of p in the interval $0<p\leq 1$ which declines monotonically:

$$h(p_1)>h(p_2) \quad \text{if} \quad 0<p_1<p_2\leq 1 \qquad (2)$$

Axiom III specifies that the message has zero information when the event has unit probability:

$$h(1) = 0 \qquad (3)$$

Axiom IV is concerned with two events, E_1 and E_2, which are stochastically independent. Hence, if their probabilities are p_1 and p_2, the probability of their joint occurrence is p_1p_2. The axiom states that the information content of the message which states that both occurred is equal to the information of the message dealing with only E_1 plus that which deals with only E_2:

$$h(p_1p_2) = h(p_1) + h(p_2) \qquad 0<p_1,p_2\leq 1 \qquad (4).$$ (Theil, 1972)

Accepting all those axioms builds the logarithmic information definition. Such a definition opens the doors to the value of and demand for information concept for the information theory.

2.3. Information and Economic Behavior

The member of an economy makes choices that implies that they have alternatives, that what was chosen was not inevitable but was in fact only one range of opportunities. That agents` opportunity set of decisions are likely the consumption bundle of an individual. We have referred repeatedly to the future in description of the opportunities open to individual economic agents. Certainly, a most salient characteristic of the future is what we do not know it perfectly. Hence, it is intrinsic in the decision-making process, whether in the economic world or in any other, that the opportunities available, the consequences of our decision, are not completely known to us. Also, the uncertainty is the fact of the economic life of the agents. The future always with uncertainty exogenous or endogenous will affect our economic life. (Arrow, 1989)

On that point, it is important to note that uncertainty is property of many decisions which do not extend into the future or at least only into the immediate future. For example, if I wish to purchase some good, especially one I have not bought recently, I may not know its price. Of course, I can ascertain it, but only by the expenditure of the time and other scarce resources. I will in general end up making a purchase without the prices of all possible substitute: it would be too costly to find them out.

Uncertainty distinguished by Knight that if calculateable then it is called risk, can be reduced by the acquisition of information. Indeed, information is merely the negative measure of uncertainty. In that point, the quantitative measure of information was investigated by many people in order to use it for an very useful modeling in the Knightian uncertainty approach.[1] Shannon's rate of transmission is in communications engineering and is not in general appropriate for economic analysis. Also, it is descripted as an economically interesting category of good but the statisticians' model of information seems appropriate for our purposes. According to that point, the signals are very important because of the observation concept is represented as signals in statistics.[2]

In this theory, the economic behavior of individuals are governed primarily by prices. From the viewpoint of the society as a whole, prices are signals by which information about scarcities is transmitted among the members of society. Here, there are two implications of even more fundamental importance in a reorientation of economic theory: (1) that information or signals have economic value and therefore are worth acquiring and transmitting even at some cost; (2) that different individuals have different information.

The economic value of information offers no great mysteries in itself. It is easy to prove that one can always do better, whether as a producer or as a consumer, by basing decision on a signal, provided the signal and the economic variables are not independently distributed. But this remark has an implication for economic decisions; the economic agent is willing to pay for information for signals. (Arrow, 1989)

We must now recognize that signals available to an economic agent are not given to him but can be added to. The space of possible decisions has been enlarged to include the acquisition of information in addition to production and consumption. Information about the behavior of the other economic agents, especially customers or workers, or about future or even present prices or qualities of goods are more straightforward examples of information whose acquisition is both possible and desired. For example, when buyers and sellers have asymmetric information about product quality, market outcomes will exhibit *adverse selection* the quality of goods traded will be biased to favor the actor with better information.

Clearly, firms do engage in information gathering. They spend resources engineering

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1 (Knight, 1921) mentioned from (Eren, 1993)

2 Statistics is analysis of the observation. Signals that represented here are likely observations. Agents can update their beliefs by signals. Therefore, for economic theory, statistical approach can be used easily.

and market research. Moreover, there are large and significant exchanges of information through the market -newspapers, business advice ,and in a somewhat modified sense of market, all of education- in short, the whole realm of the production and distribution of knowledge.

Information is not merely a good that is desired and acquired but is to some extent a commodity like others. Information market can not lead to an efficient allocation of resources. There are at least two salient characteristics of information which prevent it from being fully identified as one of commodities represented in models of general equilibrium: (1) it is, by definition, indivisible in use; and (2) it is very difficult to appropriate.

With regard to the first point, information about a method of production, is the same regardless of the scale of the output. Since the cost of information depends only on the item, not its use, it pays a large-scale producer to acquire better information than information than a small-scale producer.

Information is inappropriate because an individual who has some can never lose it by transmitting it. Information acquired by research at great cost may be transmitted much more cheaply. If the information is transmitted one buyer, he can in turn sell it very cheaply, so that the market price well below the cost of production. In welfare economics, the inappropriability of a commodity means that its production will be far from optimal. Therefore, in a competitive world will underinvest in R & D, because the information acquired will become general knowledge and cannot be appropriated by the firm financing the research.

2.4. More Information and Extreme Cases

We will see below the `more informative than` concept and definition in Chavas Approach to the value of information. This is not new; it begun to develop since 1951 the seminal work of Blackwell. These criteria, which turned out to be important for information economics, have been introduced to economic theory by Marschak (1968), and others, and later applied in a very restricted manner, surprisingly, in various economic framework.

In the recent papers, a main reason for the narrow applicability in economic models of Blackwell`s result, i.e. that `more information` is advantageous, lies in the fact that once the signal is observed by the economic agents their opportunity sets may change. More specifically, following the signal agents that they update the probability distribution and hence, the agent's opportunity sets vary. In other words, the signal may change the feasible set from which each agent chooses (under uncertainty). Consequently, the result stating that amore informative system will be preferred by all decision makers with monotone utilities, does not necessarily hold for a signal-dependent feasible sets.

Because of that in many economic circumstances where signals can be observed by all participants in the economy, consequently the opportunity sets may vary, more information may result in a worse off situation for the risk-averse agents.

For example, firstly, consider competitive producers who export their product abroad under random exchange rate. Thus, producers make their decisions about production facing uncertain profits. In the absence of currency forward/futures markets i.e., when these firms can hedge their random foreign currency proceeds, by selling part of this sum in the forward market, it might be the case that more information, conveyed by a signal correlated to the exchange rate, can be disadvantageous.

Secondly, consider individuals facing uncertain lifetime. Moreover, this random horizon results in an uncertainty about their lifetime stream of incomes. It is proved that in the absence of a life insurance market these individuals prefer more information. However, when life insurance markets operate, this results may be reversed. In this framework, signals correlated with the individual's lifetime are observed by the individual and by the insurance companies, thus affecting the insurance premia. This is about that the individual may be worse off when `more information` is derived from each signal. (Sulganik and Zilcha, 1994)

On that point, we have seen the role of information on economic theory and the relationship between information and uncertainty. In next section, we will explain to use the information concept in economic theory with game-theoretic approach.

2.5. Games with Incomplete Information

The individuals` beliefs about actions which are endogenous to the model can be easily analyzed in game theory. Economists are able to analyze the different information structure by the help of the game theory. At the level of undergraduate textbook, there is a simple way to do it. On the next section, games with incomplete information with examples will be shown. The tools of analysis in section 3.5 are more difficult than that section. In section 3.5, the tools did not enter to the textbook literature but I estimate that this growing material will be on the graduate level textbooks.

There is a restrictive manner of the games with incomplete information. It uses a transformation from incomplete information to the imperfect information which is in Harsanyi seminal articles. In the undergraduate level, uncertainty in probabilistic terms is removed with information as the true state of nature. Also, there is no noise in information signals. The particular difference between this simple method and the method which is used in section 3.5 is the noise. With noisy signals, the agents do not remove the uncertainty they face. In the simple model, the uncertainty is eliminated by the acquisition of information which has no noise in signals but in the complex model, the agents choice under uncertainty because of the noisy signals which provides information to the agents about uncertain state.

This section consists of the games with incomplete information and examples about that subject.

The analysis of games has been conducted so far under the assumption that the complete description of the game, its extensive or strategic form, is common knowledge.[1]

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[1] Informally, a fact or an event is common knowledge among agents, if it is known by each of them, if each knows that it is known by each of them, if each knows that each knows that it is known, etc.

Mathematically, let the state of the world be described by $\omega \varepsilon \Omega$, and each agent`s information represented by a partition on $\Omega$. Let $P_i$ denote agent i`s partition for i=1,.....,n and for any $\omega \varepsilon \Omega$ define $P_i(\omega)$ to be the element of P_i that contains ω. This is to be interpreted as follows: When the state of the world is ω, trader iknows only the state is $P_i(\omega)$. Thus, trader i knows that an event A has occurred if P_i

Games for which such an assumption is appropriate are called games of complete information.

In games with incomplete information, all players are supposed to know in particular the exact payoffs that opponents can obtain. Information about the opponents' is not important for determining maximin strategies or dominant strategies; it is crucial, however, for predicting which strategies are best responses of other players. Thus, complete payoff information is needed to determine a *Nash Equilibrium.* (Eichberger, 1993)

The assumption that every player knows the other players' payoff functions is demanding. Even if, in some applications, monetary payoffs can be assigned by players, for example, profits from certain actions, it is necessary to know the expected utility each player obtains from these monetary rewards to determine their best responses. Expected utilities, however, capture such unobservable individual characteristics as attitudes towards risks. It would be a several limitation for the game theoretic approach to the analysis of social interactions if games for which this information is unavailable could not be analyzed at all.

Now, we can present a game with incomplete information. This approach considers games in strategic form only but it can lead to an interpretation of incompleteness of information that carries over to games in extensive form. To simplify analysis it will be assumed without loss of generality that agents are incompletely informed about their opponents' payoffs but fully informed about the strategy sets of all players.

2.5.1. Entry and Incomplete Information

The following examples illustrate the type of the problem that arises from incomplete information about payoffs.

Consider a potential entrant to a monopolist's market. Without entry, monopolist earns three units of profit and entrant no profit. Should the potential entrant enter the market of the

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(ω) C A. Let R be the meet of the partitions P_1,....................,P_n and for any $\omega \varepsilon \Omega$ define R(ω) to be the element of R that contains ω. The definition of Aumann is that an event A is common knowledge at ω monopolist, two reactions of incumbent have to considered:

1) either the monopolist will accommodate the entrant in which case its profit will be reduced to one unit and the entrant will also make one unit of profit.

2) or it may fight entry, which will cause the entrant a loss of one unit.

The crucial question for the entrant concerns the likelihood of the monopolist fighting entry. This will depend on the outcome for the monopolist of fighting with the entrant. If the entrant knew, for example, that the monopolist would suffer heavy losses from fighting, it would be reasonable to enter the market trusting that the monopolist would not fight. Alternatively, if the monopolist were to suffer little or no loss from fighting, entry would probably be met by a fight, and consequently, the entrant would find it optimal to stay out of the monopolist's market.

Monopolist

	a	*f*
e	1,1	-1,*k*
ne	0,3	0,3

Here, *e* means the decision to enter and *ne* the decision not to enter; *a* denote the decision of monopolist to accommodate the entrant and *f* the decision to fight. The letter *k* represents the crucial payoff parameter about which the entrant is not informed. Without knowing whether *k* is larger or smaller than one. It is impossible for the entrant to predict the monopolist's reaction to entry.

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among agents 1,......,n if R(ω) C A.

2.5.2. Price Setting Duopoly and Incomplete Information

In price setting duopoly game with incomplete information, there is assumed two firms in order to simplify the model. Both firms, $I=\{1,2\}$, have no production costs, but face the following demand function for their goods:

$$d_1(p_1,p_2) = \max\left\{0, a + 0.5\frac{p_2}{p_1} - p_1\right\}$$

(1)

$$d_2(p_1,p_2) = \max\{0, b + 0.5p_1 - p_2\}$$

Prices are denoted by p_1 and p_2 respectively, a and b are positive demand parameters unknown to the respective competitor.

The two firms compete by setting prices and strategy sets are therefore $s_1=s_2=R_+$ the set of non-negative real numbers. Since firm *1* does not know the demand parameter *b* and firm *2* does not know the demand parameter *a*, neither can predict the profit of its competitor:

$$\pi_1(p_1,p_2) = (a,0.5\frac{p_2}{p_1} - p_1)p_1$$

(2)

$$\pi_2(p_1,p_2) = (b + 0.5p_1 - p_2)p_2.$$

In contrast of the section of entry and incomplete information, both firms are incompletely informed about the other firm's payoff.

In those two examples, the problem arising from the incomplete information about opponents' payoffs. Since players can no longer predict what would be a best response for the other players, they cannot determine what constitutes optimal behavior for themselves. In a seminal series of articles, (Harsanyi, 1967) suggested a method for transforming games of incomplete information into games of imperfect information for which best responses and equilibrium behavior are well behaved.[2]

The basic idea is simple. A player with incomplete information about some other player's payoff will be treated as if he were uncertain of the type of player he will face. For example, in first example, the entrant may approach the situation by assuming there are various possible types of monopolists who may oppose his, each type being characterized by a different parameter value of k. Thus, the entrant can be viewed as uncertain regarding the type of incumbent firm. If one also assumes that there is an artificial player, called nature that chooses according to some probability distribution the particular type of monopolist that will play the game then the entrant and the monopolist face the familiar environment of a game with imperfect information the entrant can not observe the move of nature. Thus, incompleteness of information about payoffs is transformed into uncertainty about the move of nature. The probability distribution over types that nature uses is the unique mixed strategy of this player. Thus, no payoff function has to be introduced for nature.

In the example of section 2.5.1 , suppose there are two possible types of monopolists, identified by $k_1= -1$ and $k_2=2$. Type k_1 represents a monopolist with heavy losses from fighting, whereas k_2 is a monopolist facing no serious cost from fighting an entrant. In addition, nature chooses with probability p type k_1 and with probability $(1-p)$ type k_2. Thus, nature decides which game is actually played.

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2 (Harsanyi, 1967) mentioned from (Eichberger, 1993)

monopolist

	a	f
e	1,1	-1,k_1
ne	0,3	0,3

Table 2. Game with probability p

Monopolist

	a	f
e	1,1	-1,k_2
ne	0,3	0,3

Table 3. Game with probability $(1\text{-}p)$

It is an important assumption of approach that players are informed about the possible types of all other players and about the associated probability distribution. In fact, this distribution and the set of all possible types must be common knowledge. On the other hand, the assumption that all players hold identical initial beliefs about possible types can be relaxed at the cost of a more complex notation.

A useful way to think about a game of incomplete information is as a two-stage procedure:

(1) At the beginning of the game, before players make a decision, nature chooses a particular player-type combination and each player learns her own type, but not the types of the other player.

(2) Then players make a choice of strategy knowing their own type and the initial type distribution.

Depending on the character of initial type distribution μ, a player may learn something about the other players' types from the information he receives about her own type. Thus, players may be able to update their beliefs in regard to the other players' types in the light of their own type assignment.

This learning or updating follows a procedure known as Bayesian learning (or Bayesian updating). In fact, the concept or having nature make a random choice first, then having the decision maker receive information about nature's choice and update the initial beliefs is useful to consider briefly Bayesian Decision Theory. (Eichberger, 1993)

Before choosing a, the decision maker receives some information w correlated with the state ω. Let W be a finite set of signals and denote by v the joint distribution on WxΩ. Before receiving the signal, the probability of a state ω will be given by, $v(\omega)=\sum_{w\in W} v(\omega,w)$, the marginal distribution v on Ω, Bayesian Decision Theory recommends choosing an action a ∈ A that maximizes expected utility, $\sum_{\omega\in\Omega} u(a,\omega)\bullet v(\omega)$.

$$v'(\omega|w') \equiv v(\omega,w')\,/\left(\sum_{\omega\in\Omega} v(\omega,w')\right) \qquad (3).$$

The difference between the conditional probability v' and the marginal distribution v reflects the informational content of the signal. Note that $v'=v$ holds if signals and states are independent that is, if $v(\omega,w)=f(\omega).g(w)$ holds for some probability distributions f on Ω and g on W. To check this claim, just substitute $f(\omega).g(w)$ into the definition of v' given in equation (3).

Bayesian Decision Theory assumes that the updated conditional distribution v' (rather than the unconditional distribution v) will be used to evaluate the expected utility of the choice of action a:

$$\sum_{\omega\in\Omega} u(a,\omega)\bullet v'(\omega|v) \qquad (4).$$

It is clear that the optimal choice of action obtained from the maximization of the expected utility (4) will depend on the signal w that the decision maker observes. In general, for different signals w, $w' \in A$ the decision maker will choose different actions $a(w)$ and $a(w')$. Hence, one can call the function $a(.)$, $a: W \mapsto A$ which indicates the optimal action choice for each signal $w \in W$ that may be observed, a Bayesian Decision function. One can call this Bayesian decision function a signal-contingent plan of action.

Let T_E and T_M be the sets of types for the entrant and the monopolist respectively. Since there is complete information about all characteristics of the entrant, just one type of entrant, say t, needs to be considered, that is, T_E, is a one-element set. The set of types for the monopolist T_M, however, has two elements k_1 and k_2. In this case, the joint probability distribution μ, on

$$T_E \ x \ T_M = \{(t,k_1),(t,k_2)\} \qquad (5)$$

takes the following form:

$$\mu = (t,k_1) = \rho \qquad \mu(t,k_2)1-\rho \quad (6).$$

Clearly, no player can learn anything from the revelation of her type in this example. For the entrant, learning the type t leads to the following conditional distribution T_M:

$$\mu_E^{'} = (k_1 / t) \equiv \mu(t,k_1) / (\mu(t,k_1) + \mu(t,k_2) = \rho$$

(7).

$$\mu_E^{'} = (k_2 / t) \equiv \mu(t,k_2) / (\mu(t,k_1) + \mu(t,k_2) = 1-\rho$$

2.5.4. Bayesian-Nash Equilibrium

Once a player has received information about her own type, he chooses a particular strategy to maximize his expected payoff. Of course, the expected payoff from any of his strategies depends on the strategies by her opponents, which in turn, will vary with the types of these players. Through a player may not know the type of his components, he can derive an conditional probability assessment of the type combination of opponents, based on the initial probability distribution over types and the information about his own type.

A player's strategy choice depends on his type, since it determines his payoff function and his information about the opponents' payoff functions. Thus, he chooses a type-contingent strategy profile. This type-contingent strategy profile is the Bayesian decision function that specifies his choice for every type he may become, one must apply the Nash equilibrium concept to these decision functions rather than to a single strategy combination: every player chooses a type-contingent best response to the decision functions of the other players. Denote by $s_i(.)$ a decision function of player $i \in I$ that, for each type $t_i \in T_i$, specifies the strategy $s_i(t_i) \in S_i$ this player will choose if his type turns out to be t_i. In addition, let $\mu(t_{-i} \mid t)$be the conditional probability of a particular type combination for the opponents t_{-i} given that player i has type t_i. For each type profile $(t_1,t_2,.....,t_I)$ that nature selects, there are conditional beliefs for each player, that is, a list of conditional probability distributions.

$$(\mu_1^{'}(t_{-1}|t),...........,\mu_I^{'}(t_{-I}|t_I)\,.$$

Beliefs of agents are, therefore, no longer identical, after they have received the information of their type.

Finally, given $s_{-i}(.)=(s_1(.),s_2(.),.........,s_{i-1}(.),s_{i+1}(.),.............,s_I(.))$ a list of decision functions for all players other than player i and $t_{-i} = (t_1,........,t_{i-1},t_{i+1},.........,t_I)$, a type combination for the other players, $s_{-i}(t_{-i})$ denotes the strategy combination of all players expect player i that will be played according to the decision functions $s_{-i}(.)$ if type combination t_{-i} occurs, that is,

$$s_{-i}(t_{-i})=(s_1(t_1),s_2(t_2),..........,s_{i-1}(t_{i-1}),s_{i+1}(t_{i+1}),.............,s_I(t_I)).$$

With this notation, one can define a Bayes-Nash equilibrium as follows:

A Bayes-Nash equilibrium is a list of decision functions $(s^*_1(.),....,s^*_I(.))$ such that for all players $i \in I$ and all types $t_i \in T_i$,

$$\sum_{t_{-I} \in T_{-I}} P_i(s_i^*(t_i), s_{-i}^*(t_{-i}), t_i, t_{-i}) \bullet \mu_i, (t_{-i}|t_i) \geq \sum_{t_{-I} \in T_{-I}} P_i(s_i, s_{-i}^*(t_{-i}), t_i, t_{-i}) \bullet \mu_i, (t_i|t_{-i}) \quad (8)$$

for all strategies holds.

In Bayes-Nash equilibrium, the decision function $s_i{}^*(.)$ associates with each type that player i may become, a strategy that maximizes the expected payoff of this player provided:

(1) The other players use their decision function $s_{-i}{}^*(.)$.

(2) The conditional probability function $\mu(t_{-i} \mid .)$ reflect the information of player i. (Rasmusen, 1994).

On that point, the model that is used in section 3.5 is analyzed with the help of the Bayesian updating. Updating beliefs with Bayes` Rule provides us to calculate the posterior beliefs from prior beliefs held by the different players. Also, the rules of the game specify each player`s initial beliefs, and Bayes` Rule is the rational way to update beliefs.

As the formula, also, more generally, for Nature`s move x and the observed data,

$$P(x|data) = \frac{P(data|x) \cdot P(x)}{P(data)}$$

In a verbal form of Bayes` Rule, we can write,

$$\text{(Posterior for Nature`s Move)} = \frac{\text{(Likelihood of Player`s Move)*(Prior for Nature`s Move)}}{\text{(Marginal Likelihood of Player`s Move)}}$$

In Table 4, it is shown Bayesian Terminology.

NAME	MEANING
likelihood	$P(data \mid event)$
marginal likelihood	P(data)
conditional likelihood	$P(\text{data } x \mid \text{data } y, \text{event})$
prior	P(event)
posterior	$P(\text{event} \mid \text{data})$

Table 4. Bayesian Terminology.

After mentioning the game theory with incomplete information, we will see the value of the information concept in the undergraduate level, in the Arrow`s approach as the communication channels approach that there are some similarities with the entropy theory and the last one is a new microeconomic viewpoint to the value of information with non-Bayesian learning.

2.6. The Value of Information

Information is valuable only if it can affect action. At the individual level, the private or public information has positive value. When we look at the social value of information, the aspect is changing. Private information that remains private was shown to be of no social value -in the sense of being purely redistributive, not leading to any improvement in productive arrangements. Public information, in contrast, does affect decisions that especially productive one, in a socially appropriate way.

The value of information in a decision making or a duopoly model were investigated by various economists. Intuitively, information is always valuable in the sense that better information on the part of one agent or one player tends to increase the utility or average payoff but it tends to decrease the one of the other.

2.6.1. Expected Value of Perfect Information

It is often of value to consider what perfect information in a complex decision situation is worth. Although perfect information is seldom available to the decision maker, its value can be used as a benchmark to evaluate the benefit of acquiring additional information. If reliable information costs \$1.000 to acquire, but the value of perfect additional information in the situation is only \$500, the additional information is obviously not worth paying for. On the other hand, if the value of perfect information is \$10.000 for the same situation, the decision maker might be willing to pay \$1.000 to get additional information that would lead to a better decision.

The expected value of perfect information (EVPI) is the difference between the expected payoff with perfect information and the expected payoff under uncertainty. If perfect information produces a profit of \$50.000, for example, and the best the decision maker could do under uncertainty is \$35.000, then the value of perfect information is the difference, \$15.000.

Also, EVPI is the difference between the payoff that would result with perfect information and the payoff that would result under uncertainty. (Hanke and Reitsch, 1991)

2.6.2 Arrow's Approach to the Value of Information

K. J. Arrow studied on the value of and demand for information. He investigated that concepts in the general equilibrium of a pure exchange economy under uncertainty. Shannon`s rate of transmission, he accepts the amount of information about the state of the world is given,

$$H = -\sum p_i \log p_i \qquad (1)$$

The most interesting economic interpretation of this quantity is given by the proposition that a communication channel with its capacity H could convey a message giving the state of the world with arbitrarily small error.

There are a lot of attempts to interpret H as a value (in the demand sense) of information. The value of a given channel is defined as the difference between the maximum utilities achievable with and without the channel. In the case of a logarithmic utility function, this does indeed lead to H, although of course the definition yields different results in general. If a channel of capacity H is installed, then the individual knows the state of the world and behave according to that situation; his return is X_i, which has a utility of log X_i . Hence, his expected return is,

$$\sum p_i \log X \qquad (2).$$

On that point, note that maximum utility achievable without information is

$$\sum p_i \log p_i + \sum p_i \log X_i \qquad (3)$$

for the logarithmic utility function.

If we compare (2) with (3), the maximum utility achievable without information, we see indeed that the value of information is precisely H.

In this case, the value of information is independent of the rewards. It can be shown that is the only such case: if the value of information independent of the rewards, then the utility function must be logarithmic.

Also, in Arrow's approach, the value of information equals to the received signals gains minus no information situation.

2.6.3. Chavas' Approach

Chavas(1993), examine the valuation of information as well as the demand for information in the broader context of a state preference approach under an ordinal representation of preferences. His starting point is the growing evidence that decision makers do not always behave according to the expected utility hypothesis. Also, there is empirical evidence that human learning is not always consistent with Bayes' Theorem.

On that study, the analysis is presented in the context of a two period model under uncertainty, using an ordinal representation of preferences. In period 2, agent makes decision by maximizing an ordinal utility function given the information available on the uncertain state of the world. In period 1, the agent can use resources to gather information.[1]

2.6.3.1. Model

Consider an agent facing a two-period problem under uncertainty where $t=1,2$ represents the two time periods. Let x be a $(n \times 1)$ vector representing period 1 decisions, $x \in X \subset R^n$, and y be a $(m \times 1)$ vector representing period 2 decisions, $y \in Y \subset R^m$. $Y(x)$ indicates that the feasible set for y can depend on the first period decisions x. The uncertainty is represented by the non-empty finite set Ω of mutually exclusive states of the world, $\Omega=\{e_1,........,e_N\}$. It is assumed that the uncertainty originates from nature choosing one state $e \in \Omega$ by the end of period 2. Between time $t=1$ and $t=2$, the agent can collect information

[1] Intuitively, the information can be interpreted to be that generated by the observation of signals or messages.

about the state that will eventually occur. This information is derived from an experiment generating a signal s observed by the agent after first period decisions but before second period decisions, $s \in S$ where s is the finite set of all possible signals.

For a given first period decision x, the signal can be characterized by a function

$$s=f(e,x) \qquad (5)$$

from $\Omega \times R^n$ to S which partitions Ω into mutually disjoint set

$$M(s,x)=\{e: s=f(e,x), e \in \Omega\} \qquad (6)$$

such that $\Omega = \cup_{s\in S}\{M(s,x)\}$. Denote that partitions of Ω by

$$P(x)=\{M(s,x): s \in S\} \qquad (7).$$

Given x, this means that $M(s,x)$, is the partition $P(x)$ if and only if it is the set of states mapped by $f(e,x)$ into the signal s. The information is provided by the partition $P(x)$ of the set Ω of states. The case of complete information corresponds to a partition of Ω in which every set $M(s,x)$ consists of a single state.

The different partitions P of the states in Ω correspond to different information structures. A basis of comparing two information structures P^a and P^b will now given by

Definition 1: **(CHAVAS)**: A partition P^a is said to be at least as fine as a partition P^b if for every $M \in P^a$ and $M' \in P^b$, either $M \leq M'$ or $M \cap M' = \varnothing$. We denote this relation by F, where $P^a\, F\, P^b$ means that P^a is at least as fine P^b. [2]

For our purpose, it will be useful to consider the vector

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[2] Note that the relation F establishes a partial ordering of information structure P. It is a partial ordering since it satisfies reflexivity, transivity and antisymmetry. (F is reflexive if PFP for every P. F is transitive if P^aFP^b and P^bFP^c imply P^aFP^c. F is antisymmetric if P^aFP^b and P^bFP^a then $P^a=P^b$.

$\bar{y} = \{y(e_1),........,y(e_N)\} \in Y(x) \times Y(x) \times Y(x) \times ....\times Y(x) \subset R^{mN}$, where $y(e) \in R^m$ denotes the second period decision made under state e. Then, the problem is for the agent to evaluate the vector $(x,\bar{y})$. This raises two issues: does there exist a utility function representing the agent's preferences over $(x,\bar{y})$? And what is the impact of learning and information acquisition on the agent's decisions?

After observing the signal s, the agent determines that the true state is in $M(s,x)$. The restriction is, here, that not knowing which state in $M(s,x)$ is the true state, the agent must make the same decision y for any $e \in M(s,x)$.

Then, consider the agent's decisions made to according to following problem:

$$v = \sup_{x,\bar{y}} \{U(x,\bar{y}) : x \in X\}$$

$$\bar{y} = \{y(e_1), y(e_2),.......,y(e_N)\} \in D(x,P) \qquad y(e) \in Y(x) \qquad e \in M(s,x) \qquad (8).$$

$D(x,P) = \{\bar{y} = y(e) = y(e');$ for; $e \in M(s,x);$ and all; $e' \in M(s,x);$ for all; $M \in P(x)\}$.

This problem is decomposed by Chavas into subproblems by using backward induction and conducting the optimization in (8) stage-wise. In first stage, the second period decisions y is made conditional on x:

$$V(x,P) = \sup_{x,\bar{y}} \{U(x,\bar{y})\} \qquad (9).$$

In the second-stage, the first period decisions are:

$$v = \sup\{V(x,P(x) : x \in X\} \qquad (10)$$

The existence of a solution to problem (9) follows from the assumptions. In particular, given $x \in X$ and a continuos utility function $U(x,\bar{y})$ there exist an upper semicontinueous correspondence

$$y^*(x,P) = \{(y^*(e_1,x,P),.......,y(e_N,x,P)) : y^*(e,x,P) \in Y, e \in \Omega\}$$

satisfying

$$U(x,y^*(x,P)) = \sup\{U(x,\bar{y}): y \in Y(x), e \in \Omega\}$$

where $V(x,p)$ in (9) is continuous function of x.[3]

Assume the existence of a solution to problem (10), that X is a compact set and $v(x,P)$ is a continuous function of x. Then, there exists a choice $x^* \in X$ such that $V(x^*,P(x^*))=\sup_X\{V(x,P(x)):e \in X\}$.[4]

2.6.3.2. The Value of Information

It is well known that, under expected utility hypothesis or Bayesian learning, the decision maker cannot be made worse off by obtaining costless information. In that section, we firstly, look to the non-negativity of the gross value of information of Chavas' approach without the expected utility hypothesis or Bayesian learning.

The assumptions are that the agent's decisions x^* and y^* are made according to problem (8), the value of information can be measured in terms of monetary compensation schemes. To see that, assumed that the feasible set $Y(x)$ includes a budget constraint involving the agent's initial wealth $w \in R$. On that point, the value function $V(x,P)$ in (9) takes the form $V(w,x,P)$, where V is a strictly increasing function of w. For a given x, consider two information structures P^a and P^b satisfying

$$P(x)FP^aF\Omega \quad \text{and} \qquad P(x)FP^bF\Omega$$

Then, using the information structure P^a as the reference point, the exchange value of P^a and P^b can be measured by the value A that satisfies implicitly

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[3] This establishes the existence of an optimal policy function $y^*(s,x,P)$, where $y^*(s,x,P)=\{y^*(e,x,P)$ for all $e \in M(s,x)\}$. This policy function gives the optimal choice of y at $t=2$ following the observation of signal s, conditional on the first period decision x.

[4] The first period, decision x^* represent *ex ante* decisions that do not depend on the states since they are the same for all states $e \in \Omega$. In the contrast, the second period decisions y^* are *ex post* decisions with respect to the signal s: they are made after the information provided by the signal s is obtained (but before the state e is known) **[CHAVAS (1993)]**.

$V(w,x,P^a)=V(w+A,x,P^b)$ (11)

For a given x, the value A is in (11) is the maximum amount of money the agent is willing to receive (or pay if negative) *ex ante* to replace the information structure P^a and P^b and be indifferent between the two situations. Alternatively, if the P^b is the reference point, then the exchange value of P^b and P^a can be measured by the value B that satisfies implicitly

$V(w,x,P^b)=V(w\text{-}B,x,P^a)$ (12)

On that point, the value B in (12) is the smallest amount of money the agent willing to pay (or to receive if negative) *ex ante* to replace information structure P^b and P^a and be indifferent between the situation.

Here, Chavas find some useful insights. First, A may not be equal B. Second, while the magnitude of A and B need not be identical, their sign is always the same, i.e. $sign(A)=sign(B)$.

Definition 2: The information structure P^a is said to be at least as informative as the information structure P^b if $A \geq 0$ This relation is denoted by G, where $P^a G\, P^b$ means that P^a is at least as informative as P^b.

Also, considering two definition of Chavas, the relation F 'as fine as' and G 'as informative as'. This proposition can be constructed that if any information structure P^a and P^b satisfy $P^a\,F\,P^b$, then $P^a\,G\,P^b$, with $A \geq 0$ and $B \geq 0$.[5]

Because of the sign of A and B, the agent is willing to pay a non-negative amount of money to have access (costlessly) to finer information structure.

On that perspective, relaxing some of the assumptions typically found in the literature does not affect the general desirability of information in economic decisions. Also, we can analyze the value of information on a non-Bayesian process. This is a new approach and it gives to economist more powerful tools to understand the decision problems under uncertainty.

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[5] In this proposition the complete ordering G is always consistent with the partial ordering F.

3. INFORMATION IN MARKET STRUCTURE

Information gathering and transmission have been gaining a larger role in the economy over time. It was estimated that production, processing and distribution of information goods and services account for over a quarter of GNP in the USA and the papers in Edmund Phelps`s volume (1970) showed the presence of imperfect information gives firms market power at least in the short run and often in the long run as well.[1] It is found that if information is costly, each small firm obtains market power, and the equilibrium (if one exists) is characterized by prices above competitive levels and sometimes price dispersion as well. The relevant market structure with imperfect information is not perfect competition but rather monopolistic competition. (Salop, 1976)

In this chapter, we will discuss first the role of uncertainty in duopoly and after that, we will pass to the role of information in market structure with all possible perspectives.

3.1. Role of Uncertainty in Different Type of Duopoly

The extent to which firms can choose price or quantity must, of course, crucially affect the nature of competition. If they have some choice, however, the extent to which firms want to choose price or quantity may be important.

When firms know both the market demand and, in equilibrium, other firms` choices of strategic variables, each firm is different between setting price and quantity. But when firms are uncertain about their residual demands, because shocks to market demand are unobservable or because the level or type of strategic variables chosen by other firms are unknown, each firm's choice between setting price and setting a quantity becomes important. This events generally give different expected losses relative to the maximum profit that could be achieved if the residual demand perfectly known.

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1 (Phelps, 1970) mentioned from (Salop, 1976)

Weitzman (1974) emphasized the importance of the choice between setting price and quantity under uncertainty. The objective function in his model was expected total surplus. In Klemperer and Meyer (1986), firms maximize expected profits. The analysis incorporate their choices between prices and quantity strategies into an oligopoly model to determine the strategic variables used in equilibrium.

In the absence of uncertainty, there are four possible types of equillibria. (price, price), (quantity, quantity), (price, quantity) and (quantity, price). Among these equilibria, there are different output levels, and intensity of competition.

When exogenous uncertainty about market demands is introduced, the oligopolist can not be indifferent between setting price and quantity. On that point, the Nash-equlibrium is not exactly appears in four duopoly games under uncertainty.

In order to see the setting price and quantity, let we show the example of consulting. If a consultant charges a fee per hour, he is setting price. On the other hand, he might set a fixed fee per consultation. If he spends less time on any one client when his office busy than when demand is slack, so that his total work day is constant, he is, in effect, setting a quantity and adjusting price according to demand. (Klemperer and Meyer, 1986)

If we consider a monopolist facing the uncertain linear demand and having a cost function, the monopolist strictly prefer to set quantity (price) when marginal cost slope upward (downward) and is indifferent only when marginal costs are flat. On the other hand, considering a differentiated products duopoly facing an uncertain linear demand that is not observable by either firm at the time strategic variables are chosen, after that if marginal cost slope upward, the unique Nash-equilibrium involves both firms` choosing prices. Constant marginal cost allows, the all four Nash equilibria, except if the goods are perfect substitutes, in which case only the (quantity, quantity) and (price, price) equilibria exist.

Now, we are looking at the point that firm's preferences over strategic variable, and hence the nature of Nash equilibria in the game, are sensitive to the manner in which random disturbances affect demands. Specifically, if uncertainty affects the slopes of linear demand curves, rather than just the intercepts, then price competitor will arise for flat or not excessively rapidly rising marginal cost curves. If a monopolist faces a random slope but fixed vertical intercept and, at the point that expected setting quantity profit minus expected setting-price profit is strictly negative (positive), so setting price (quantity) is strictly preferred.

Also, the effects of the uncertainty have different results when they are on intercept or slope. The Figure 1 is the case of random slope. It is more complex to estimate with or without information the actual demand curve. Although, in Figure 2, there has the same difficulty but there is another factor that firms can estimate the inference of the demand, so in the analysis that uncertainty on demand function, economists generally study on random intercept.

In the model of uncertainty arises from exogenous demand shocks. It could alternatively arise from each firm's uncertainty about its rival's behavior, owing to uncertainty about some characteristic of the rival's cost or demand function. There is thus no need for

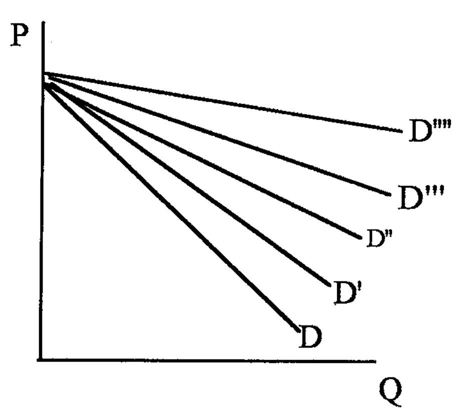

Figure 1.Random Slope

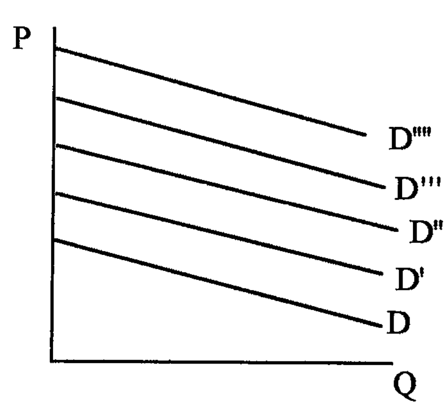

Figure 2. Random Intercept

actual variation in market conditions: a lack of perfect information about the rival's behavior is sufficient to give firms strict preferences between setting prices and setting quantities. Whichever the kind of uncertainty, an arbitrarily small amount can move us away from the case with four equilibria.

There are three factors of firms` preferences between quantity and price setting as strategic variables in the presence of uncertainty. The slope of marginal costs (upward, downward or flat), the effect of the random disturbance on demand , (especially inferences in prediction) and curvature of the demand.

When marginal costs are steep, setting quantity is preferred because the *ex post* optimal quantity is relatively stable compared with the output that would result from setting a price and producing to meet market demand. Also, when marginal costs rise rapidly, firms will compete as Cournot players, but that when marginal costs become flatter, firms will be forced to compete on price. Also, marginal costs has an important role on competitive behavior when demand is uncertain.

If the other costs of choosing strategic variables are taken into consideration, Klemperer and Meyer (1986) would find that competition in industries with rapidly increasing marginal costs were most often through quantities, whereas competition in industries with flatter or decreasing marginal costs were most often through prices. Firms` preferences between strategic variables are stronger in industries with more elastic demands and greater uncertainty.

3.2. Value of Information in a Duopoly Model

Sakai(1985) investigated the value of the additional information in a duopoly model in which the cost functions of the firm are not known with uncertainty. He uses many types of information structures in order to acquire the information, he uses the own knowledge of firms of the probabilities of cost c_1 and c_2. On the first phrase, he find that the uninformed firm has an incentive to acquire information but an informed firm has an incentive not to share the information.

On his model, there are two firms with x_i output level and

$$mc_i = c_i x_i \qquad (i=1,2) \qquad (4)$$

is the marginal cost function of firm i assumed to be linear and cost parameters c_1 and c_2 are random variables whose joint distribution $\phi(c_1,c_2)$ is known to both firms. Also, it is common knowledge.[1]

After that, Sakai build the information structure of firms for symmetric and non-symmetric and shared information. On that point, he concentrated to the symmetric case and calculated the conditional expected profit of firms and consumer surplus.

To measure the value of additional information, investigating the problem of how better information available to either firm affects the welfare of both firms along with the welfare of consumers (consumer surplus).

On that point, it results in a decrease in the expected consumer surplus. Also, when each firm gathers private information about its own cost or the firms exchange information, this is a damage for third passive players also consumers.

Consequently, compared the case of no information for the two firms, any form of

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[1] Considering the probability distribution on (c_1,c_2), it is convenient to assume that is a normal distribution with mean $(m_1,m_2)>0$, variance $(s_1^2,s_2^2)>0$, and the correlation coefficient $r(-1<r<1)$.

improvement in information structure tends to the beneficial all firms and consumers; therefore, the social value of information is always positive in the sense.

If there is a simultaneous and symmetric improvement in information for both firms: then the expected profit of each firm must increase whereas expected consumer surplus must decrease.

When the information is not symmetrically distributed between the two firms some seemingly counterintuitive results might be obtained. First, better information on the part of a certain firm may not help that firm in achieving a greater expected profit, so that additional information may be detrimental to the firm to be informed. Second, the effects of better information available to one firm on the welfare of the other firm, and also on the welfare of consumer, can be ambiguous in sign: the latter two parties would be better off or worse off. Third, it may or may not be desirable for a firm to acquire information about its own cost rather than the rival's. All these possibilities depend on the values of variances of the costs and their correlation coefficient. (Sakai, 1985).

3.3. Acquisition of Information

The efficiency of prices in acquisition of information has been extensively studied in competitive models of financial markets. However, information problems are as prevalent in product markets as they are in financial markets. Firms continually act to acquire information on market conditions. Such information is generally not solely of firm-specific value but also of relevance to other firms; hence, there is a problem how incentives for information acquisition among firms interact.

For example, in a duopoly market in which heterogeneous firms acquire costly private information about the stochastic market demand prior to their production decisions. Private information reduces the uncertainty in market demand and helps firms make a more informed decision on the level of production. The major issues in that example are: which firm would acquire more information? Which firm has a larger elasticity of demand for information?

Research that investigating the optimal information acquisition by individual economic agents has grown substantially in recent years. There are a lot of previous studies that include the analyses of the noisy rational expectation models of a competitive financial market. According to that studies, the common point is that in general equilibrium amount of information acquisition is a decreasing function of the cost of information and the precision of the noise. A interesting result is found in Verrecchia (1982), where heterogeneous risk averse individuals are allowed to acquire more information, because they make-up riskier portfolios and thus demand more information to protect their riskier positions.

There are studies that optimal information acquisition by homogenous risk neutral firms in an oligopolistic industry. They find that the equilibrium amount of information acquired by each firm is a monotonically decreasing function of information cost, the slope of the demand function, and prior precision of the random demand function, but independent of the level of constant marginal cost.

Hwang (1993) analyzed the case of heterogeneous firms. The difference among firms in his model is their cost functions. Firms are assumed to have non-identical increasing marginal costs. In this work, he finds that a firm with a smaller slope of marginal cost function acquires more information at the equilibrium. A smaller slope of the marginal cost function calls, *ceteris paribus*, a larger adjustment of quantity to a given change in residual demand. A knowing point for everybody is that an increase in information cost reduces the equilibrium amount of information acquired by each firm. Also, the price elasticity of demand for information is smaller for a firm with a smaller slope of the marginal cost function.

The effects of a change in demand function parameters (slope and prior precision) are quantitatively the same as the case where firms have the identical marginal production cost function. An increase in the slope or in the prior precision decreases the amount of information acquired by each firm. The relative effect of these changes is greater in percentage terms for the firm which acquires a smaller amount of information. This was also the case with a change in the marginal cost function of a firm decreases its information acquisition, but increases the amount of information acquired by its rival.

Consequently, marginal cost appears as an important factor that determines the amount of acquisition of information. Smaller marginal cost provides to obtain more information for firms.

3.4. Demand for Information

In economies, uncertainty and asymmetric information plays a dual role. The information available to an economic agent forms a part of the description of the agent , and information itself can be viewed as an economic commodity, albeit one of a quite special type. Allen (1986) refers the information as a differentiated commodity. Also, there is an infinitely many kinds of information are available in the economy. Commodity differentiation for information refers the different types of information structure and they may be (imperfect) substitutes for each other. Hence, one can distinguish the amount of information from its quality or type.

Information signals provide a good illustration of the importance of distinguishing among information of various type. Observing the same realization of a random variable twice does not constitute twice as much information as observing it once, while a second independent observation may provide additional different information than tenth independent observation. Each realization of each random variable contains different information except in degenerate cases.

Consider that the information, here, takes the form of a written report or data on a computer tape. Think also of the case in which the report or tape has no aesthetic value, but it is useful only for the information that it contains; in particular, consumers receive no direct pleasure from reading these reports. Some other examples of information include magazines and newspaper, various financial newsletter, scientific instruments, laboratory tests, government statistical reports and documents, professional services such as medical examinations, consumer marketing surveys and on-line computer network services such as *internet*. In these examples, it is the information content per se that is desired and the consumer knows the type (but not the particular realization) and quality (or at least its probability distribution) before purchase, either because the information can be well specified (i.e. standard medical test, time series data for a specified period for particular aggregates, an instrument whose capacity and reliability can be documented or a simplex algorithm computer program which can solve linear programming problems of a particular size to a certain degree of accuracy within a given time period on a specified computer) or because licensing requirements or reputational considerations effectively discourage misrepresentation.

In Allen`s model, agents information acquisition decisions are rendered endogenous; optimizing behavior (given budget constraints) defines demands for information and other commodities. Any trader who has purchased information from someone else (or who has retains some of his initial information) may condition his demand for ordinary commodities on that information. Endogenous information acquisition is considered for the purpose of conditional expected utility maximization in a competitive model without production. In particular, a consumer is unable to reproduce an unbounded number of copies of the information at no cost. Also, this is best justified by pointing to the datedness of most types of information. For example, last year`s market stock advice or last week`s newspaper is worthless, so that making many copies or using the information and then passing it along to someone else is precluded.

However, the works cited above are partial equilibrium studies of a market for a single information good, and they employ special functional forms for utilities and/or specific distributional assumption (such as normality) for random variables. These papers have focused on the rational expectations and public goods aspects of endogenous information decisions and were motivated by issues arising in the financial asset market literature.

Allen stresses indivisibilities in information transactions and permits differentiated information which can not necessarily be parameterized by numbers such as time, variance and covariance. There is no assumption about normality or constant absolute risk aversion. This is because of the cost of this generality that prices do not transmit information here; also, rational expectations features are completely absent.

The characterization of information as a commodity inherently raises several obstacles to its inclusion in microeconomic models. In addition to product differentiation, the essential special features of information include its indivisibility aspects (information inherently comes in discrete units) and the fact that one becomes satiated with information of a particular kind when one unit has been acquired.

3.5. Incomplete Information in Different Market Structure

Economists in particular have shown a talent for bringing every problem back to a world of certainty where all solutions are known or can be easily found.

This is not to say that economists have not worked on uncertainty. Cournot, most popular mathematicians in the world for economists because of its oligopoly model, typified the way in the uncertainty is introduced and then taken out by assumptions. He posed a situation in which two firms sell mineral water from the same spring and have no costs. (Cyert and DeGroot, 1987)

Assume that a linear inverse demand function,

$$p = a - b(q_1 + q_2) \qquad (1)$$

The Firm 1`s total revenue (profit) is,

$$pq_1 = aq_1 - bq_1^2 - bq_1q_2 \qquad (2)$$

Firm 1 maximizes its profit by choosing a value of q such that,

$$\frac{d(pq_1)}{dq_1} = a - 2bq_1 - bq_2 - bq_1\frac{dq_2}{dq_1} = 0 \qquad (3)$$

Similarly, firm 2 maximizes profit by choosing a value of q_2 such that,

$$\frac{d(pq_2)}{dq_2} = a - 2bq_2 - bq_1 - bq_2\frac{dq_1}{dq_2} = 0 \qquad (4)$$

Cournot handled the uncertainty contained in the derivatives $\frac{dq_2}{dq_1}$ in (3) and $\frac{dq_1}{dq_2}$ in (4) by assuming that each was zero. That is, he assumed that neither rival would change output as a result of a change in the others output. The Cournot model is a dynamic process that reaches to the equilibrium with the changes of the output level of the firms each time simultaneously. Each time that one firm makes a change, it does with expectations that its rival will keep output constant. There is no learning mechanism for either firm but they reach equilibrium through this inappropriate use of market information on incorrect assumptions of the Cournot model.

We can see the uncertainty-information relationship in the Cournot model only on the assumption of the equations (3) and (4) that is equalized to zero. Also there is no necessity for acquisition of information for firms because they faces a non-stochastic linear demand function, no costs and no effect of the rival`s behavior.

Other variations of this approach can clearly made. One can assume values other than zero for the derivatives in (3) and (4), and a different equilibrium will be found. Stackelberg developed a series of different models by assuming the possibility of one firm being a leader and the other follower. The follower continues to expect a zero changes in output by the leader, whereas the leader is assumed to know the reaction function of the follower. (Cyert and DeGroot, 1987)

This is the first inspiration of the incomplete information on the Cournot model because the leader knows both of the reaction functions but the follower has no such a chance and information structure of the firms is different such as if we assume the information structure has the elements as *Cartesian Product* of the knowing of the reaction function, the information structure is a set that is called *A* and contains *{(1,1);(1,0);(0,1);(0,0)}*. *"1"* is for knowing the reaction function and *"0"* is used for not-knowing of it. *(L, F); L* is used in order to be denoted the leader`s information about reaction function and *F* is for follower. In the *Stackelberg* model, leader can acquire all available information but the follower can only reach to the *(0,0)* and *(1,0)* by assumption. Therefore, the leader acquired the information *(1,1)* and the follower can only afford for the information structure *(1,0)*. So, we can solve such a problem and obtain the leader-follower solution. This is a solution that obtained by the help of the calculus.[1]

On the literature, the uncertainty takes its place in the uncertain linear demand function or cost function of the firms. A duopoly model, where firms have private information about an uncertain linear demand, was analyzed by various authors. Vives (1984) studied that if the goods are substitutes (not) to share information is a dominant strategy for each firm in *Bertrand (Cournot)* competition,. If the goods are complements the results is reversed. Furthermore, the following welfare results obtained:

i) With substitutes in *Cournot* competition the market outcome is never optimal with respect to information sharing but it may be optimal in *Bertrand* competition if the products are good substitutes. With complements the market outcome is always optimal.

ii) *Bertrand* competition is more efficient than *Cournot* competition.

iii) The private value of the information to the firms is always positive but the social value of information is positive in *Cournot* and negative in *Bertrand* competition.[2]

Generally, on the literature, the uncertain part of the linear demand function is the random intercept such as on the Crawford and Sobel (1982) paper. Authors investigated that information equilibrium and incentives for sharing information among firms. Their results are different because of their different assumption. This has arisen from the different cost structure, product differentiation and behavioral factors as collusive or incentives for sharing information .

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[1] In the game theory, Stackelberg model (leader-follower problem) has no equilibrium because the solution depends on the characteristics of the managers of the firms in order to fight for more information and the historical background of the markets.

[2] Cournot and Bertrand differentiation could be seen in the Bertrand critique of Cournot contribution. Bertrand devotes half a page to taking Cournot to task for his chapter on oligopoly: He cites two faults: first, the firms would certainly collude and make larger profits than the Cournot equilibrium afford and, secondly, even if they were not to collude, they would choose prices rather than output levels. Collusion is impossible to believe or unworthy to study but second point has more substance. It is reasonable to suppose that firms are price rather than quantity choosers and therefore, the negative social value and efficiency effects arise from that point.

Private information reduces the uncertainty in market demand and helps firms make a good decision capability on the level of production. We present the characteristics of the equilibrium in a two stage model, where firms determine the amount of information to acquire in the first-stage and then in the second stage determine the level of production based on their private information. In this section, a model of a duopoly market in which heterogeneous firms acquire costly information about the stochastic market demand prior to their production decisions.

The model is essentially the same as the one used Li, McKelvey and Page (1986)), Vives (1988) and Hwang (1993), except for the specification of the production cost function:[3]

$c(q_i) = c_i(q_i) + (e_i/2)q_i^2 \quad c_i > 0,\ e_i > 0 \qquad (5).$

Firms face a stochastic linear inverse demand function, $P = \theta - bQ$ where

$Q = \sum q_i, \quad b > 0,$

and random intercept term θ, is distributed with finite mean μ and precision h (inverse of variance σ^2.[4]

The precision h is that is also equal to $1/\sigma^2$.[5] .The distribution of θ is common

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[3] The difference among firms in our model is their cost functions. Firms are assumed to have non-identical increasing marginal costs. There are two reasons to introduce strict convexity of the cost function. First, as LMP and Vives have shown, the identical firms` decisions on information acquisition are independent of the level of constant marginal costs, we suspect that their decisions on information acquisition are the same as the decisions made by homogenous firms. More importantly, Kirby (1988) shows that the slope of the marginal cost function plays an important role in oligopoly firms incentive to share private information and oligopoly firms with sufficiently large slope of the marginal cost function have mutual incentives to share their private information. We expect that nonconstant marginal cost functions will have similar effect on the firms` information acquisition decisions as Hwang(1993) accepted.

[4] The random intercept θ is a variable or parameter that can shift the inverse linear demand curve as a change on taste or the other shiftable effects.

The set of random intercept θ is given as $D=(\theta_1,\theta_2,\ldots\ldots\ldots\ldots,\theta_n)$.. The slope cannot change.

The analysis is on the firms` imperfect information about the evolution of the market demand curve. On that model, Firms never directly observe the position of the previous output of rivals. Riordan (1986) showed that firms do draw inferences about the position of the demand curve from the past observations on prices. On this study, firms` conjectures about rivals` behavior are not ad hoc, as in the static models, but are based on a characterization of equilibrium behavior in an explicitly dynamic model.

[5] In the Li, McKelvey and Page (1986), precision is explained by the way that θ is generated to

knowledge to all firms. Firm i receives private information on the true value of θ in the form a noisy signal, $Z_i = \theta + \varepsilon_i$,where the random noise ε_i has zero mean and precision t_i and $cov(\theta,\varepsilon_i)$. The signal received by the firms are independent conditional on θ and $E(\theta \mid Z_i)$ is assumed to be affine in Z_i .Each firm can increase the precision t_i of information at a constant marginal cost λ.

3.5.1. An Argument In a Competitive Market

In a competitive market, production strategy for firm i is a function of $q_i(.)$ which associates an output to signal received. Suppose that we have a market equilibrium characterized by $q_i(.); i \in [0,1]$ that is,$q_i(.)$, $i \in [0,1]$, is a Bayesian Nash equilibrium of our economy. $q_i(s_i)$ maximize $E(\pi_i \mid Z_i) = q_i\, E(P(q^*;\theta) \mid Z_i) - C(q_i)$ where q^* is average output. An interior equilibrium $q_i(.)$ is thus characterized by $E(P(q^*;\theta) \mid Z_i) = C(q_i(Z_i))$; given that firm i has received signal Z_i the expected market price must be equal marginal production costs.

How does the market outcome compare with full information first best where total surplus (per capita) is maximized contingent on the true value of θ? Given θ, total surplus with average production q is,

$$TS(q;\theta) = \int_0^q P(x;\theta)dx - c(q),$$

where $x = \Sigma q_i$ and obviously, first best production $q^0(\theta)$ is given by the unique q which solves $P(q;\theta) = C`(q_i)$. If firms were able to pool their private signals they could condition their

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a distribution $g(\theta)$ and then that y_i is generated according to $h(y_i \mid \theta, t_i)$, where

$t_i = 1/E(Var(y_i \mid \theta))$.

Thus, information level of each firm is a measure of the expected precision of the signal it is to receive. The higher its information level, t_i , the lower the expected variance. Both $g(.)$ and $h(. \mid \theta, t_i)$ are assumed to have finite variances. Also, for any fixed t_i , t_j , and θ is assumed independent of y_j , given t_j , and production to the average signal which equals θ and attain the first best by producing $q^0(\theta)$. Will a competitive market, where each firm can condition its production only on its private information replicate the first best outcome ?

A necessary condition for any (symmetric) production strategy $q(.)$ to be first best optimal is that, conditional on θ, identical firms produce at the same marginal costs, namely.

$$C'(q_i(Z_i) = C'(q^0(\theta))$$

but increasing marginal costs this can happen only if $q_i(Z_i)=q^0(\theta)$ which is basically the perfect information case. Therefore, we should expect a welfare loss in a competitive market with noisy signals since a production strategy which is not based on the average signal cannot attain the first best. Also, in a competitive market with symmetric firms with strictly convex costs which receive private noisy signals about an uncertain demand parameter, there is a welfare loss with respect to full information first best.

We show that no symmetric production $q(.)$ and therefore, in particular no competitive production strategy, can attain the first best.

The market expected total surplus contingent on θ is given by,

$$E(TS|\theta) = \int_0^q P(x;\theta)dx - E(C(q(Z_i)|\theta) \qquad (6)$$

This is strictly less than the first best $TS(q^0(\theta);\theta)$ since $TS(q^0(\theta);\theta) \geq TS(q^*(\theta);\theta) > E(TS|\theta)$.

The first inequality being true since q^0 is the first best, the second since cost function is strictly convex. $q^*(\theta) = E(q(Z_i)|\theta)$, the signal are noisy (which means that given θ, $q(Z_i)$ is still random) and in consequence;

θ .

$$C(q^*(\theta)) < E(C(q(Z_i)|\theta) \qquad (7).$$

On that point, a necessary condition for the market outcome to be first best optimal is that marginal costs be constant. This is the same considered by Palfrey(1985). He finds that if the information structure is "regular enough" first best efficiency is achieved in the competitive limit.[6]

3.5.2. Equilibrium Strategies

On the above mentioned model, the solution of the expected value of θ on conditional to the Z_i is,

$$E(\theta|Z_i) = E(Z_j|Z_i) = \mu + \delta_i(Z_i - \mu) \qquad \delta_i = t_i/(t_i + h) \qquad (8).$$

$$\text{cov}(\theta, Z_i) = \text{cov}(Z_i, Z_j) = 1/h.$$

If there is no noise on the signal ($h=0; t=0$) and then, the firm obtains the true value of the θ. We can find the expected value of θ,

$$E(\theta|Z_i) = \mu \qquad (9).$$

where $\delta_i = t_i/(t_i+h)$ is a monotonically increasing function of t_i and $\delta \in [0,1]$. We will use t_i and δ_i interchangeably as the precision of information in the following analysis.

In the first stage of the game, each firm determines the amount of information to acquire by selecting the precision level t_i, the precision acquired becomes public information. The realized value of the signal Z_i, which each firm receives in the second stage, remains private information. In the second stage, each firm determines its output level conditional on

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[6] An interesting consequence of convergence theorem relates to the more general question of pricing in competitive markets under uncertainty. To the extent that the model here is a reasonable description of a perfectly competitive markets, price will precisely equal marginal cost, even if individual firms face a lot of uncertainty. The reason that price converges to marginal cost is that the Cournot game successfully aggregates all the firms` private information. Uncertainty is resolved in the competitive limit. (Palfrey, 1985)

its signal value Z_i and other public information.

Previous studies like Vives(1988) characterize the competitive equilibrium as the limit of a sequence Cournot oligopoly equilibria as the number of firms "eventually become price takers in the limit". Like Hwang(1995), this definition is not useful for our purpose of comparing competitive and oligopoly equilibria with a finite number of firms. In the present paper, the same approach will be specified as competitive firm that is in the neoclassical world but as a firm that determines its output in the second stage conditional on its information, taking the expected price $E(P \mid Z_i)$ as given and taking the rival firm`s output strategy into account. Also, the competitive firm knows that a change in its output does not affect the expected price.[7]

Let $\kappa = \delta E(q_j|Z_i) / \delta q_1$ denote the expected conjectural variation, where

$\kappa = -1$ for competitive firms,

$\kappa = 0$ for Cournot oligopoly firms,

$\kappa = 1$ for monopolist firms.

In the second stage of the game, each firm determines its output to maximize the expected profit conditional on its private information Z_i. The conditional expected profit for firm i can be written as,

$$E(\pi_i|Z_i) = (E(P|Z_i) - c)q_i - (e/2)q_i^2 - \lambda t_i \qquad (10).$$

In this stage, in order to obtain the unique *Bayesian* linear output strategy for firm *i*, let $\tau = e/b$ be the ratio of the slope of the marginal cost function to the slope of the demand

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7 In Hwang(1995), this specification is equivalent to specify the competitive equilibrium as a member of the parametric "conjectural variations" oligopoly model with finite member of firms. The conjectural variations oligopoly model is subject to some well merited criticism, but it provides us with a convenient way to "to capture the idea of varying degrees of competition". The general comparative statics in quantity setting conjectural variations oligopoly is presented by Dixit (1986) and Quirmbach(1988). In Quirmbach`s paper has the subject about demand shift effect which very important us in order to study about the random intercept of inverse linear demand function.

function and $\phi=\tau+\kappa+2$. Then, the strategy is given by,

$$q_i = \alpha_i + \beta_i (Z_i - \mu), \qquad (11)$$

where

$$\alpha_i = (\mu - c) / (b(\phi + 1)) \qquad \text{and} \qquad \beta_i = \delta_i (\phi - \delta_j) / (b(\phi^2 - \delta_i \delta_j))$$

(12)

The subscripts *c,d* and *m* are denoted the competitive, oligopoly and monopoly firms respectively. It is easy to verify from (11) and (12) that

$$E(q_c) = \alpha_c > E(q_d) = \alpha_d > E(q_m) = \alpha_m \qquad (13)$$

The ex ante expected output level is the largest at the competitive equilibrium, followed by the oligopoly and then by the monopoly equilibrium. The expected output levels are independent of information precision. If there is no information, the equilibrium output is fixed at α_i, and firms either underproduce when the demand is high, or overproduce when the demand is low.[8]

Information helps firms to adjust their output to changes in demand. The direction of adjustment is not perfect, because a higher signal does not always imply a higher demand due to noise in the information signal. The magnitude of the output adjustment to the signal is represented by the adjustment factor β_i, which is an increasing function of the firm`s own information precision, and a decreasing function of the convexity of the cost function and a rival firm`s information precision.[9]

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[8] In Gal-Or (1985), when the firms behave as Nash-competitors, pooling private information has two effects on the profit of the firm. When a firm observes a signal of low demand and reveals it to others, it reduces the likelihood that its competitors "overproduce". However, when it observes a signal of high demand and reveals it to others, it reduces the likelihood that its competitors "underproduce". On that point, there must be intensive to share information in a market. Sharing information can obstacle o lot of inefficient situation, if there is a pooling information activity among firms.

[9] If all firms have information of the same precision, then a change in the signal has the largest impact on the competitive firm`s output and smallest impact on the monopoly firm`s output. ($\beta_C > \beta_d > \beta_m$). This reflects the instrintic differences in firm`s responses to the changes in demand under

Given the second stage equilibrium strategies, the first stage choice of information precision is found by maximizing the *ex ante* (unconditional) expected profits $E(E(\pi \mid Z_i)$ with respect to information precision t_i. Substituting (11) into (10) and taking expectations with respect to information variable Z_i, gives unconditional expected profit for firm *i*,

$$E(\pi_i) = \left[\frac{b(\kappa+\phi)}{2}(E(q_i))^2\right] + \frac{b(\kappa+\phi)}{2}\operatorname{cov}(q_i^*, q_i) - \lambda t$$

$$E(\pi_i) = \left[\frac{b(\kappa+\phi)\alpha_j}{2}\right] + \frac{b(\kappa+\phi)}{2}\frac{\beta_i^2}{h\delta_i} - \lambda t \qquad (14),$$

where q_i is the equilibrium output under full information:

$$q_i^* = (\theta - bq_j - c)/b\phi.^{10} \qquad (15)$$

The first term in (14) represents the profit at the ex ante expected output before firm receive information and second term, the total benefits of information. Firms can improve their average profits by adjusting outputs in the direction of the changes in demand as information signal indicates. The average degree of correct output adjustments to the changes in residual demand is measured by the covariance between full information optimum output and the equilibrium output in the second term. This is called the size of *output calibration.*[11]

The total benefits of information are proportional to the sizes of output calibration, where the proportionality factor ($b(\kappa+\phi)/2$) represents the curvature of the profit function. The curvature of the profit function is an increasing function of the firm type parameter κ, which is

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certainty ($\delta_i=\delta_j=1$ and $Z_i=\theta$) that equilibrium output becomes $q_i=\beta_i(\theta-c)$, where $\beta_i = 1/[b(\phi+1)]$ represents the marginal effect of the changes in demand on the equilibrium output. This marginal effect is largest for competitive firms and smallest for the monopoly firms.

[10] This equation is as same as in Hwang(1995) and Vives(1988). They used the same way to show the full information equilibrium output.

[11] The equilibrium output is predicted value in a linear regression of the full information output on the information signal, $q^*_i=\alpha_i+\beta_i Z_i$. The size of output calibration $cov\ (q^*_i, q_i)$ can thus be taken as a measure of the goodness of fit in the regression. This can be divided into two components: $cov\ (q^*_i, q_i) = cov\ (\theta, q_i) - b cov(q^*_i, q_j)$.

which is denoted as expected conjectural variations, and hence is the smallest for the competitive firms and the largest for the monopoly firms. On the other hand, the size of output calibration is the largest for the competitive firms and the smallest for the monopoly firms, when the firms have information of the same precision. This is because the competitive firms respond to their information signal most aggressively. The relative sizes of the total benefits of information are thus a priori indeterminate: they depends on the net effects of the two countervailing factors.

Suppose that information of identical precision is given exogeneously to the firms. Then, the total benefits of information is,

(a) smaller to the competitive firms than to the oligopoly and monopoly firms

(b) greater or smaller to the oligopoly firms than to the monopoly firms as the precision of information is low or high.

In order to show the mathematical convenience of the above expression, we evaluate (11) at the symmetric information precision $\delta=\delta_i=\delta_j$ to obtain the total benefit of information.

$$TB(\delta) = \delta(\phi + \kappa) / 2bh(\phi + \delta) \qquad (16)$$

If we substitute $\phi_c = \tau + 1$, $\phi_d = \tau + 2$ and $\phi=\tau+3$, it is straightforward to show $TB_c < TB_d$ and $TB_c < TB_m$. It is also easy to verify that $TB_d > TB_m$ if and only if $\delta < \delta^*$, where

$$\delta^* = 0.5(\sqrt{(\tau + 2)(\tau + 4)} - (\tau + 2)). \qquad (17)$$

When information is costly the first stage choice of information precision determined where the marginal cost of information is equal to the marginal benefit of information, which also varies with the types of the firms.

The symmetric equilibrium $t=t_i=t_j$ in the first stage is the solution to $MB(t)=\lambda$, *where* the marginal benefit of information $MB(t)$ is given by

$$MB(t)=\frac{b(\kappa+\phi)(\phi^2+\delta^2)(1-\delta)^2}{2b^2h^2(\phi+\delta)^3(\phi-\delta)} \qquad (18) \qquad \text{(Hwang, 1995).}$$

The first term in (18) is the curvature effect as discussed above. The second term is the marginal effect of information precision t_i on the size of output calibration. Also, an increasing in information precision t_i increases the frequency of output calibration in the right direction and makes firms adjust more aggressively and thereby increases the size of output calibration. This is called the calibration effect of information precision. As in the case of total benefits of information, the same comparison can be made among the marginal benefits of information and equilibrium information precision across different types of firms requires a comparison of the net effects of the two countervailing factor: curvature effects and calibration effects.

After that, we can obtain a result that at the interior precision of information, (a) competitive firms acquire less information than oligopoly and monopoly firms, and (b) oligopoly firms acquire more or less information than monopoly firms, depending on the information cost and the convexity of the cost function.

The convexity of cost function plays a crucial role in acquisition of information . When the convexity of cost function is sufficiently low, oligopoly firms calibration effects are sufficiently larger compared to the monopoly firms and can offset their smaller curvature effects. Lower convexity of cost function, gives to firms courage to behave more aggressively respond to their information. Therefore, relative levels of equilibrium information precision depends on the convexity of cost function and the information cost (λ).

3.6. Information Sharing in Oligopoly

There are several articles in recent years to motivate the oligopolists in order to share their private information with his rivals. Those articles show that the relevant parameters for information sharing are the nature of competition, the type of private information and the relationship of products.

On that articles, the effects of agreements among oligopolists to exchange private information about demand conditions have been analyzed by Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984), Gal-Or (1985), and Li(1985). The standard assumptions in this literature are that (1) reporting and verification are costless, (2) the oligopolists will behave non-coorperatively in their pricing or output decisions, whether they share information or not, (3) the only variable about which the firms are uncertain is the intercept of a linear demand curve with known slope, and (4) each firm receives a noisy private signal that contains information about the true intercept. Clarke(1983) and Gal-Or (1985) show that oligopolist who behave as Cournot (i.e. quantity setting) competitors in a homogenous goods industry will not choose to share their private information. Vives (1984) demonstrates in a differentiated product setting that duopolists` incentives to share private information about demand depends on whether their products are complements or substitutes and upon whether the firms behave as price or quantity competitors. (Shapiro,1986)

The issue of information sharing is particularly important from anti-trust perspective. To discover what types of information exchange should be encouraged or discouraged to enhance competition, it is first necessary to understand the behavior of unregulated firms in the exchange of information about the uncertainties they face.

Intuitively, the recipropal exchange of information may have different influences on firms` probability. First, receipt of more accurate information about the demand or costs permits the recipients to choose the strategies that are more responsive to actual circumstances and hence improves the profits. On the other hand, the pooling of information may effect the degree of correlation of output decisions. The reverse effect occurs when firms exchange information about private costs. In Cournot oligopoly, an increase in the correlation of output decisions among firms implies a decrease in the output, and hence a decrease in the profit of a single firm if its revenue function is concave. Therefore, one may conjecture that the firms are willing to exchange information about costs, but not about demand. (Li, 1985).

Earlier studies find that identical Cournot oligopoly firms in a homogenous product market do not have mutual incentives to share their private information about stochastic market demand, unless they also corporate on strategy once the information has been shared. In the analysis of information sharing, firms are assumed to follow the conventional noncoorparative strategies in their output or price decisions once information is shared. Hence, if all firms in an industry are observed to pool information without compensating each other, they must be cooperating to restrict output on the basis of the homogenized information. (Hwang, 1994)

Kirby (1988) disputes this conclusion. She considers risk neutral Cournot oligopoly firms with identical cost functions and identical qualities of information and shows that firms have a mutual incentive to share their information when the cost function is sufficiently convex and/or demand is sufficiently elastic. Therefore, information sharing does not necessarily imply illegal collusion on output. Convexity of the cost function should be taken into account in the decision of legality of information pooling agreements.

Because of the restrictive assumption of homogenous firms, Kirby`s contribution is limited, but her results has legal implications. On that point, a trade association typically involves firms with different cost functions but this differentiation brings some problem on the agenda. As a question, is there several effects of cost differentials on firms` incentive to share information?

The beginning point is the beneficial information sharing among firms. On that perspective, economists investigate the following questions: (1) which firm has more incentive to share information? (2) Under what conditions is the firm with less incentive willing to share information? (3) When information sharing is not mutual beneficial, is it likely that a firm gains enough from sharing information, such that it can entice the unwilling firm into sharing information by compensation?

In order to find answer those question above, economists uses a two-stage game model .On that studies, there are several results. First, the firm with a less convex cost function has more incentive to share information. This result is the Kirby (1988) interpretation for the effect of the convexity of cost function on the incentive to share information. He argues that the value from sharing information is higher when the cost function is more convex, because a higher convexity of the cost function implies a higher cost "production error".

Second, firms may not agree to share information when there is a large difference in the convexity of cost functions, even if each cost function satisfies Kirby`s convexity condition. The firm with a sufficiently more convex cost function does not have an incentive to share information. However, the firm with less convex cost function gains enough from information sharing, such that it can entice the unwilling firm information sharing through compensation.

Finally, when firms have different qualities of information, under certain conditions, the firm with superior information has the incentive to share with a firm whose information quality is substantially lower.[1] That is, there exist conditions under which the benefit of information sharing induced by the convexity of cost function is large enough to offset the negative effect

1 Clarke (1983) demonstrates that, when firms have identical constant marginal cost, a firm with superior information will never give up its information advantage through sharing, while a firm interior

from the loss of the initial information advantage.

In Hwang (1994), firms determine to share or not to share its private information in first stage of the game with the rival firms. In second stage, each firm receives the realized value of its own signal, as well as, its rival's signal value if the first stage decision is to share information. Each firm then determines its output level, conditional on the set of available information, to maximize its expected profit.

In the second stage of the game, if the first stage decision is not to share information, the equilibrium output strategy has two components, (1) the expected equilibrium quantity of firm i before signal is received, (2) the *ex post* output is adjusted in proportion to the difference between the signal value and the prior mean of the random intercept term. Also, the second components includes the marginal adjustment factor which depends on the slope of the demand function the slopes of the marginal cost functions and both firms` quality of information.

The marginal adjustment of firm's output to a change in its signal increases as the slope of its own marginal cost function decreases and as the slope of its rival's marginal cost function increases. The output adjustment to a given signal is thus larger for a firm whose slope of the marginal cost function is smaller.

If first stage decision is to share information, and firms have identical cost functions and qualities of information, both firms respond to the signal equally. When firms differ only in their cost functions, each firm responds equally to both signals and the amount of output adjustment is smaller for the firm with a steeper slope of the marginal cost function. When firms have identical cost function, but differ in the quality of their information, each signal does not affect both firms` output by the same amount, and higher quality signal will have a greater effect.

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information wishes to share.

Hwang (1994) shows the benefit from the sharing information with covariances. This result is obtained by subtraction the expected profit for firm *i* in the shared-information game with the unconditional expected profits for firm *i*. For the first decision, information sharing always increases the covariance between the two firms` output strategies which has a negative effect on expected profits. Therefore, firm *i* has an incentive to share information if and only if information sharing increases its demand-output covariance and the increment is sufficiently large enough to outweigh the negative effect due to the change in the covariance between output strategies.

The effect that information sharing has on the demand-output covariance is a priori indeterminate. There are two factors that affect the demand-output covariance. One factor is the prediction accuracy of the random intercept of the demand and another is how well the rival is expected to adjust its output level to demand.

Additional information acquired through information sharing increases the prediction accuracy of demand. Since the rival firm also obtains additional information, the rival firm's output is expected to be more concordant with demand in the shared-information game. That is, covariance between random intercept and rival's expected output is also greater when information is shared. The relative magnitudes of these two factors depend on other parameters, and hence the effect that information sharing has on the demand output covariance is generally indeterminate.

The prediction accuracy of demand depends only on the quality of available information, while rival's firm's cost function. Thus, the characteristics of the rival firm's cost function have an important effect on firm *i*`s incentive to share information. In particular, if the rival firm's cost function is highly convex, its output is not expected to change much when demand changes.

In the position of that firms have private information of the same quality, but different cost functions, firm *i* has a greater incentive to share information than firm *j* if and only if $mc_i < mc_j$. Like in Kirby`s claim that more convex cost function increases the incentive to share information because the cost of production "errors" higher. He ignores the effect of the convexity of cost function on the prediction accuracy (errors), and partly because the comparison of the expected costs of production errors between shared and private information cases is not equivalent to the comparison of expected profit.

The exchange of information among oligopolists has long been treated with suspicion by antitrust authorities. The exchange of consumer-specific pricing information is widely regarded to facilitate oligopolistic coordination by enhancing cartel enforcement mechanisms. Interfirm exchange of cost or demand information also has been greated especially in U.S antitrust law. In general, there is a tension between the anticompetitive effects of information exchange and the possible efficiencies arising from more widespread dissemination of accurate information. (Shapiro, 1986)

On that point, an important issue in enforcement of antitrust law and regulations on trade associations` statistical programs is whether or not information-pooling agreements among oligopoly firms can be considered prima facie evidence for illegal collusion. (Hwang, 1994)

Gal-Or (1985) investigated that in an oligopoly where firms observe signals about linear stochastic demand, private information is never revealed if firms behave Nash competitors in setting output levels. The restriction of the analysis to a symmetric environment is taken place by some dominance of one firm over others because it enjoys a superior technology, or has access to more precise information. He found that the stronger incentives may arise if technological uncertainty rather than demand uncertainty or if prices rather than quantities are chosen.

Li(1985) as the same Gal-Or (1985) but much strictly, found that firms never reveal private information if there is uncertainty about the intercept of the demand function, and private information is perfectly revealed if there is uncertainty about marginal cost of production.

But Kirby (1988) demonstrates that homogenous oligopoly firms have a mutual incentive to share their private information when the cost function is sufficiently convex, hence the convexity of cost functions should be taken into account in the decision of legality of information-pooling agreements.

In Hwang (1994) generalize Kirby`s result because a trade association typically involves firms with different cost functions and/or different precision of information. He analyzes the heterogeneous firms from the beginning point of that opinion. After that, when firms have different cost functions, they have mutual incentive to share information regardless of the differences in their cost functions if all firms` cost function are extremely convex. When firms have information of different qualities, under certain conditions, the firms with superior information may find it mutually beneficial to share its information even if the rival firm has substantially lower quality information. The necessary conditions for this event are that the slope of the marginal cost sufficiently larger than the slope of the demand curve and the information qualities are generally low. The firm with inferior information always to share its information.

4. CONCLUSION

Information sometimes taken to mean knowledge, for example, an accumulated data or evidence about the world. From this point of view, information is a stock magnitude. But the word may also denote an increment to this stock of knowledge, in the form of message or an item of news. On the other hand, in the individual`s optimizing choice between the alternatives, there are two behavior: (1) taking immediate terminal action, or (2) acquiring better information first, with the aim of improving the ultimate terminal decision to be made.

This crucial role of information appears in all of the branches of economics. In this study, the role of information was examined in the firm theory. The main point is the firms which face the stochastic demand. We examined the effects of private noisy information about uncertain inverse demand function on the expected welfare at the competitive, oligopoly and monopoly equilibria. In this model, the precision of information is exogeneously given. In that case, the expected welfare is the largest at the competitive equilibrium and the smallest at the monopoly equilibrium.

On the other hand, we analyzed in this study the incentive to share private information among oligopoly firms. The related literature about this subject was examined. The firms that have different cost function have mutual incentives to share information. In order to compare the results, the other studies with their different assumptions about subject were mentioned.

When one firm has moderately convex cost function mutual incentives exist only if the difference between the slopes of the marginal cost functions does not exceed a certain limit. An interesting result is greater for the firm whose cost function is less convex. Therefore, when firms do not agree to share information, it is the firm with the more convex cost function who refuses to join the information exchange program, contradicting the Kirby`s intuitive explanation.

Computers have greatly improved the lives of economists. The estimation of econometric models, the manipulation of datasets, word processing, and Econ-Lit are just a few examples of computers' impact. However, computer networks may dramatically change the way we work. Already we have seen hints with electronic mail, mailing lists, on-line card catalogs, access to U.S. government data, and the start of an on-line working paper culture. This summer, back issues of the American Economic Review will go on-line, and across academia, there are almost 200 peer-reviewed electronic journals with hundreds of U.K. journals going on-line this year.

In short, a fully networked world could offer much easier access to the information (working papers, articles, bibliographical information and data) for economists. This aspect is very interesting if we consider that the firms which face the uncertain situation acquire more easily the information. In the future, the fully networked world may remove some of the information structure such as incomplete, imperfect or private information structure.

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