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# **INFORMATION AS AN ECONOMIC COMMODITY**

*Report*



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# I. Generalities

This lecture is intended as a catalogue of questions and viewpoints, raising some serious problems with the concepts supplied by standard economic theory. I don't promise to give much in the way of interesting answers; indeed, one interpretation of what I say is that in some sense there cannot be any fully definite theory of economic behavior.

Specifically, I want to argue that the role of information in the economy is essential to our understanding of its workings. By itself, this proposition would seem to be so evident that it is not worth discussing. However, I want to argue that the process of acquiring information is more complex than is usually understood. As a result, the consequences for the economy are much different than the standard picture of economic theory. This approach may suggest some explanation of the occasionally erratic behavior of the modern economic system which has been observed throughout the last two centuries and more.

You doubtless all know that I have devoted a considerable part of my career as an economist in the elaboration of the general equilibrium approach to the understanding of the economy. One question that was much discussed when I was a beginner was the incorporation of uncertainty into general equilibrium theory. I was very proud that I developed a formalism which accomplished that. The economic agents take account of the possible random events in advance and know what will happen under each possible realization. Hence, news will affect the markets, but it cannot cause a runaway reaction.

I seem then to be repudiating a good part of my life's work. Actually, I was always aware of some issues, and a careful reading of my papers will show reservations and caveats. I don't intend this lecture to be a defense of myself, but I make a few remarks explaining my past thinking.

What I want to stress in this lecture is that information is endogenous to the economic system. Information comes in many shapes and forms, but two important things can be said. One, it plays an essential role in directing the allocation of resources above and beyond the role of the prices of the usual commodities. Two, it is itself a commodity, being both scarce and valuable, but it has properties quite different from the usual. The special properties of information make the usual modeling of allocation through a market of limited use.

My approach will be to start with the standard approach of economic theory. I assume that consumers are rational with regard to

consumption and with regard to risk-bearing. Firms maximize profits, although that term requires definition. There are markets, at least until they prove to be difficult or impossible. The markets clear at some appropriate price.

As we shall see, the program leads to some conclusions but also deep difficulties. It is these that we want to emphasize.

Given this background, I want to introduce information as an explicit economic variable, governed by the same motivations as other economic choices. But the peculiarities of information as a commodity are stressed.

To introduce the subject and show its significance, I will review the different ways in which information affects the economic system.

## II. The roles of information in the economic system

That information is important to the economy might seem to be self-evident. Ever since the work of Robert Solow, it has been evident that economic progress has been propelled for the most part by increase in knowledge, what we usually think of technological progress. This is information about the transformation of goods from one form to another. In the usual neo-classical system, these are embodied in the production possibility sets.

In the simplest version, the change takes place exogenously, usually represented by an exponential factor in some part of the model. (Of course, exponential growth forever is not possible, but it could conceivably be an approximation.) Even in this simple account there are or ought to be complications. Technical change, after all, occurs in specific industries. It will change relative prices. If I am considering investing in that industry, I might postpone the investment to take advantage of a superior process. I might worry that a competitive product will become cheaper and so not invest today. In short, anticipating technical progress will have effects on current economic behavior.

A second and even more obvious complication is that technological change doesn't just happen. It is the result of a decision to seek it, and it is costly. There is sometimes a tendency to regard technological change as a by-product of scientific research, itself not directed to a particular technology and so exogenous. Even if this were an adequate formulation for sci-

ence, which it is not, there is still a large expenditure on research and development needed to achieve viable and useful alterations in technology.

There is another issue, clearly of great importance in understanding economic history and economic development. This is the question of diffusion of knowledge. It is clear that just as production functions differ over time, they also differ among countries and even regions at a given moment of time. In fact, they differ considerably among firms in a single country. That diffusion is not instantaneous requires explanation.

There are undoubtedly many factors here, but surely one is the idea of intellectual property; new productive ideas are often owned. But this is not really compatible with the view that technological progress is exogenous. It means that a firm owns an idea because it has invested in it. There is also a second factor in the slowness of diffusion; acquiring already existing information is itself costly. This point should be obvious to any professor watching his or her students expending considerable effort in understanding the course material.

We already see some lessons for the economics of information. (1) The information an individual has is a matter of choice, not a given. (2) Information is, in general, costly. (3) Information is not only about the natural world and its laws but also about the actions of others; the actions of others in turn depend on their information.

Most other kinds of information found in the economic system are even more clearly information about others within the economic system. The financial sector, now greatly expanded in size, is essentially an industry based on collecting information about the parts of the economy and acting on that information. The actions include purchases and sales of securities but are not confined to what are ordinarily thought of as markets. They also include two-party contracts, such as extension of credit to firms (commercial credit) and to individuals (personal loans, mortgages on real estate).

The circular nature of information in the market was given explicit recognition by Oskar Morgenstern in a paper of 1934, before his joint work with John von Neumann on game theory. He had been concerned with business cycle forecasting, as head of the Austrian Business Cycle Research Institute. He began to question whether forecasting was possible, by recognizing what we have already observed, that in effect individuals are forecasting each others' forecasts.

At about the same time, in 1936, John Maynard Keynes, in "The General Theory of Employment, Interest, and Money", likened the capital market to an advertising campaign run by an American brewery. The advertisements contained the pictures of six models, and each

participant was to choose one. The participant got a prize if his or her choice had the most votes. Clearly, the participant should choose, not the one he or she deems the prettiest, but the one which others think is the prettiest. But clearly this process leads to an infinite regress. Keynes's point is really much the same as Morgenstern's; rational forecasts are circular.

Of course, mutual dependence does not necessarily mean a failure of the system. The standard theory of general equilibrium shows that one can have a consistent outcome. I return to this question a bit later.

### III. Rational theory of information acquisition

One kind of behavior under uncertainty is the acquisition of information. Hence, a rational theory of information acquisition can be and has been deduced from the general theory of behavior under uncertainty.

Rational behavior under uncertainty is usually modeled as follows. Individuals have some choice of actions, such as investment in various risky alternatives, which yield an uncertain outcome, say,  $x$ . That is, the outcome depends on factors outside the control of the individual and about which they are uncertain. Then the hypothesis of rational action says that individuals have a utility function,  $U(x)$ , and they choose their actions so as to maximize,  $E[U(x)]$ . I am not going to examine the empirical validity of this hypothesis, but rather use it as a starting-point.

What we must consider here is the acquisition of information as one of the actions the risk-bearer might undertake. The bulk of our analysis under uncertainty has dealt with the purchase of securities with random future prices and other uncertainties of payment, the analysis of production with uncertain outcomes, or devices to maintain consumption in the presence of random shocks to income and wealth. However, it has always been somewhat true that individuals facing uncertainty try to acquire more information about the uncertainty.

The optimal choice of information has been studied especially by mathematical statisticians. A simple form is that of sampling. There is some parameter, relevant to the individual's decisions but unknown to it. This might be, for example, the mean return to be expected on a security. We can make observations which are governed by a probability distribution dependent on that parameter. Then our uncertainty about

the parameter after making the observations has changed; usually, it has been reduced.

We can formalize this change in uncertainty by the use of Bayes' Theorem. Suppose our initial uncertainty about the mean return is represented by a probability distribution. Call this the *prior* distribution. Then, after drawing the sample, Bayes' Theorem yields a new distribution, called the *posterior* distribution. This is the distribution to be employed in making optimal investment decisions. It is easy to show that, in investing a given amount of money, it is always better to optimize given the posterior.

But of course sampling is in general costly. A statistical prototype is acceptance sampling. Suppose a firm orders a large number of items. Some of them may be defective. Testing any item is expensive. The firm takes a sample and tests each one. It then makes a decision to accept or reject the entire lot, taking account the posterior distribution of defects and the costs and benefits of accepting or rejecting the lot. One further decision is the size of the sample. The larger the sample, the lower the probability of a wrong decision, but also the higher the cost.

In terms of an investment portfolio, an individual may devote some of his or her initial wealth to research, then use the rest of the funds to invest on the basis of the posterior distribution.

Hence, the investor has to allocate his funds among a number of alternative commodities, which include not only different securities but also information. However, there is one special way in which the demand for information differs from usual demand functions. The information is typically about the *rate* of return, not the amount. Hence, its value to the investor depends on the amount invested. We would expect that those with more wealth will buy more information, so that the rate of return on what they have invested should on the average be higher. There is some evidence that this is in fact true empirically. This proposition certainly implies that individuals in the market face different distributions of returns, since they buy different amounts of information.

There are alternative sources of information. It follows that there is a tradeoff between the quality of the information and its cost. Investors may tend to use readily available information, such as transactions on observable markets, rather than better but scarcer information. They may also tend to use information from those to whom they are close for non-economic reasons.

For all these reasons, it is clear that the market will not reflect all the information available and that the information used by different parties will be different.



## IV. The market as information: theory

Let me turn to a significant strand of the economic literature, especially in the last century. This is the idea, conveyed in several different forms, that market prices are themselves information. This is an idea which has hovered between a metaphor and an expression of reality.

An early expression is Adam Smith's reference to the "invisible hand." I should say immediately that historians of thought have debated extensively about Smith's meaning. The context is a little odd, since it distinguishes between domestic and foreign investment. I have read the relevant passages very carefully, and I find the usual interpretation to be correct. Each investor seeks out the most profitable investment; the result is to increase national income. Clearly, the prices are being used as signals, but only in a metaphorical sense. Each individual takes the prices as facts and does not analyze them as a statistical sample.

In short, the "invisible hand" really merges into what we would call today, "welfare economics." It would appear that, by a happy coincidence, competitive equilibrium is efficient in some sense only made clear by gradual developments in economic analysis. One aspect of the matter is the question of computation. However defined, competitive equilibrium is a matter of solving a quite complicated set of equations. The great Italian economist, Vilfredo Pareto, analogized the market to a computer; in fact, at least in the French translation of his major work in economics, he used the word now standard in French for, "computer." Indeed, he extolled the market as able to solve systems far beyond the capacities of then-current computing, that is, in 1904.

The idea that prices might convey information in a more literal sense seems to have started with the analysis of possible socialist systems. By the end of the 19th century, socialist parties had significant representation in European parliaments, and the prospect that socialism might be enacted through democratic processes. This raised the question how a socialist system would actually operate. Pareto, though an economic liberal and anti-socialist, was interested in the question, and encouraged a younger economist, Enrico Barone, to develop a model of a socialist economy (1906). Here, the central ministry controls resources. Prices are announced, and the firms and households announce their demands and supplies at those prices. Prices are varied until supply equals demand. Al-

though Barone's paper contained all the essence of the later discussion, it was unknown until it was rediscovered by Hayek.

The discussion became a public issue just after the end of World War I, particularly in Austria, where the prospect of a socialist takeover appeared imminent. Ludwig von Mises argued that a socialist system was impossible. Joseph Schumpeter apparently disagreed and urged a student, Kläre Tisch, to explain how a price system could serve as signaling, an analysis very similar to Barone's, which of course he knew nothing about. There followed a spate of articles, frequently not known to others, repeating, extending, and clarifying the process. Friedrich von Hayek is perhaps the most famous of these authors, but Jacob Marschak, Fred Taylor, and especially the Polish economist, Oskar Lange, must be mentioned.

The basic issue began to be seen as a problem in computing and information costs. A centralized system required the transmission of all the knowledge in individual firms to a central authority, an impossibly costly transaction. Market socialism tried to achieve an optimum by an iterative approach in which the only items of information transmitted were the supplies and demands for the successive price approximations.

A fuller formalization of the issues and an enormous clarification was the paper of Leonid Hurwicz (1960). In particular, he emphasized what is the key requirement implicit in the market socialism discussion, what he called the "privacy-preserving" principle. Each unit was supposed to receive messages and then, on the basis of its private knowledge, send out new messages, according to certain rules. When the messages all agreed, the process stopped, and the agreement contained in the messages was carried out. The messages were from a limited set. He demonstrated, for example, that under the usual assumptions that hold for competitive equilibrium, the price system was in some sense at least as efficient in informational terms as any other.

## V. The market as information: in practice

Let us turn to the question, to what extent can markets guide investment activity. The costs are incurred in the present, but the returns occur in the future. What are the relevant markets for investment activity? There are very few. That is, there are very few markets for the sale of fu-

ture goods. There are of course securities markets, including markets for derivatives. These are commitments to pay money in the future. These do not allocate specific goods, but they do help allocate goods in some general sense across time.

But an interesting question arises. Why are there any transactions? There are of course some straightforward explanations; individuals are at different points in their life cycle, so that older people sell and younger ones buy, or some people or firms have some need for resources for other purposes, foreseen or not. But clearly most transactions in existing securities are due to disagreement in expectations, which corresponds to a point already made. Let look at some examples.

The wheat futures market is about as well-organized a market as one is likely to find. Yet, its behavior accords only in part with the basic theory of markets. Wheat is largely purchased by millers at the time of harvest for making flour. The standard account argues that risk-averting millers want to buy wheat in advance for delivery at harvest time. They do to avoid uncertainty in the price they pay. Like most people who buy insurance, they expect to lose on the average; they are buying price certainty at price. It is then expected that the speculators who sell the futures will profit. They buy the crop as it comes to market, so they profit by the difference between the then current price and the futures price. They participate on the basis on an expected profit.

A detailed study showed that the miller did indeed lose, as the standard theory would hold. But the speculators fell into two categories. One consisted of the brokers who also traded on their own account. They profited, but their incomes were not any higher than they probably could earn elsewhere, say, bank officers. The other group were outsiders. They lost money on the average. The question is why did the outside speculators enter at all? Clearly the information available to them was defective.

The deviations from theory in other futures markets are much more dramatic. Consider for example the market for foreign exchange. The explanation for buying foreign exchange is that international sales are not delivered instantaneously, and it may be some time before delivery is made and payment made. The foreign exchange, for example, the ruble-dollar ratio, may change during the intervening program, and the seller may want to hedge against this uncertainty. This would imply that the demand for foreign exchange in a year should be roughly equal to world trade. In fact, the transactions are about 300 times greater. Clearly, most of the transactions are between people who have no legitimate hedging interests. Instead, these markets are used essentially for betting among people with different information and beliefs.

Still another example where behavior of a future-oriented market departs from standard economic theory is the behavior of the standard stock market. In theory, the price of a stock should be the discounted value of its dividends with adjustment for risks. This is, after all, a summary of a very long future. It should not change abruptly from day to day. Yet, a change in the aggregate stock market index of 1% or 2% in one day is considered quite normal. Again, this implies that the information sets underlying the market price is remarkably unstable.

The behavior of the securities markets and other credit transactions in the current crisis hardly suggests very good response to information. Indeed, even earlier, there was an incident which should have given warning. In 1998, a very successful hedge fund found itself in trouble. This fund operated by investing its clients' money to arbitrage some quite small deviation from a normal relation. These deviations were so small that they yielded little profit unless borrowed money were used. The fund was in fact borrowing 97% of the amount it invested. When their returns fell short, they were temporarily unable to repay. The amount borrowed was so great that their creditors and even the Federal Reserve Board considered it as a threat to the safety of the creditors and therefore to the financial system as a whole. It is the behavior of the lenders that is so difficult to understand. They had a lot at stake, and they were experts in understanding risks. Of course, they had had only favorable experiences with this hedge fund, and this was part of their information set.

This particular situation was ultimately resolved with little loss, except to the fund itself. The favorable outcome may have been unfortunate in building up a lack of concern to the greater speculation that followed. The latter was due to mortgage-backed securities, and again the financial sector proved unable to assemble the information to cause caution on the part of the market. The underlying facts were clear enough. The ultimate source of value was the housing market, where prices were rising rapidly. There were many comments in the financial press on the possible unsustainability of this rise, so the financial sector should have at least recognized the uncertainty of the situation and curtail its lending.

Similarly, the market and the credit system seems to have been unable to anticipate the problems with Greek debt. While there was evidently some concealment on the part of the Greek government, I find it hard to believe that diligent study would not have at least raised suspicions.

## VI. General equilibrium with markets for future and uncertainty

In the final section of my talk, I want to review briefly the general equilibrium theory for allocation over time and under uncertainty. I want to reexamine why the markets called for in the theory do not exist and what are the implications for economic behavior of their failure to exist.

Erik Lindahl seems to have been the first to note that capital theory could be regarded as ordinary value and equilibrium theory with commodities that are given dates (so steel delivered next year is a different commodity from steel delivered today). Equilibrium means that the market for each commodity at each date clears. Lindahl first published his ideas in a paper in Swedish in 1929, translated into English in 1939. John R. Hicks came up with a similar approach to capital theory in 1939, though it was embedded in a more sophisticated and more fundamentally based theory of firm and consumer behavior.

It turned out that a parallel construction can introduce uncertainty into general equilibrium theory. Following the general approach to probability theory as set forth by A.N. Kolmogorov, we refer to a *state of nature* as a complete description of the world (or at least the parts relevant to it). Uncertainty then is represented by a probability distribution over states of nature. We then identify commodities not only by date but also by the state of nature. A typical market transaction would be to commit to deliver a physically described commodity at a given date if a given state of nature occurs. I proposed this construction in a paper in 1952, and it was subsequently considerably deepened by Gerard Debreu (1959).

Clearly, however, this extremely rich set of markets is very far from reality. As we have already seen, only a few such markets exist. Since a market should emerge if there any mutual gains from its creation, we have to ask why this should be. I will return to at least one explanation in a minute or so. We may also ask what the implications of this market failure is. We have already seen them. They create a need for forecasting, with all the problems already sketched. If markets for all future dates and for all risks existed, then the prices at which these transactions will take place is known, and no further information will be of any use. It is the market failure that makes information-seeking so important.

But we must observe that to have a general equilibrium which handles time and uncertainty, there are some hidden informational assumptions. Consider for example the simplest model for equilibrium over time,

where there is privacy-preserving in Hurwicz's sense. Suppose each individual has no uncertainty about his or her future income. However, some individuals wish modify the time stream of consumption from that of income. They might want, say, to lend in period 1, and then consume more in period 2, in total, period 2 income plus repayment with interest of the loan. This sounds pretty straightforward, but how do we know, even in this simple case, that the borrower can or will desire to repay. To be sure, we can impose some penalty, that is, regard the borrower as bankrupt. But the borrower may prefer this outcome, having consumed a great deal in period 1.

Hence, even if all the relevant markets existed, it would be valuable to acquire information, in this specific information about the borrower. Banks classically have had as a main part of their business investigating the creditworthiness of those it considers lending to.

It is also true that uncertainty and informational problems can prevent markets from emerging. Consider the contingent market defined earlier. For it to exist, it is necessary that all parties understand what state of nature has occurred. This is a condition on the information held by the economic agents involved.

We have come to one of the most important development in economic theory in the last sixty years, the recognition that individuals hold differing information. The term, *asymmetric information*, has been coined, and it includes such well-known phenomena as moral hazard and adverse selection. The concept is very important in understanding a number of different fields, especially those where the commodity dealt with includes a good deal of information. Medical practice and insurance and financial services are two good illustrations. The failure of the market to operate too well in this circumstances has led to a literature, usually called, *mechanism design*, on creating incentives, usually within firms, to achieve some improvement.

Finally, associated with these modifications of general equilibrium theory, I must return once more to the acquisition of information.

Suppose first that each individual has a little bit of information. A price emerges, which reflects everybody's information. This price thus conveys something about everyone else's information, and therefore increases everyone's information. One can continue this process until an equilibrium is reached. This approach has been developed by a number of authors.

Suppose however the information is not initially given to the agents on the market. They may choose to acquire some, and so start the process. But, as Grossman and Stiglitz have pointed out, if the price is highly

informative, then it doesn't pay any particular agent to acquire information. But if no one acquires the information, then it never enters the market price, which is therefore uninformative.

## VII. Multiple sources of information

We have seen the extreme importance of information in guiding the economic system in view of the absence of adequate prices for the future and for risky events. Let me just make a few simple remarks, designed to emphasize the possibility that changes in information and belief may play a major role in the rather sudden and radical alterations in economic activity to which the capitalist system has been subject since its rise to dominance.

A first remark is that information, though a commodity, has very different properties from ordinary commodities. It can be used or sold, but it still remains in existence and in the hands of its original owner. Hence, the smooth reactions we usually expect in well-running markets may fail.

Second, getting information is very subtle. Essentially, we make inferences about the inferences made by others. Even seeing that someone will buy at the price I offered to sell tells me something about his information. We are quickly led to infinite regresses. There is no necessary contradiction, but the reasoning processes may not be capable of being carried out, so we stop short.

All these characteristics suggest the possibility of excessive reaction to a minor change in information.

I know I haven't answered my questions, but I hope some of you will be stimulated to think further on the role of information in the economic system.

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Arrow Kenneth J.

**Information as an economic commodity**

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