THE NEW ECONOMICS OF INFORMATION

by

Jack Hirshleifer and John Riley

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In part because of the tremendous extent of recent contributions, in part because one of us surveyed the then-current state of the subject at these meetings four years ago (Jack Hirshleifer, 1973), we here focus on a few selected themes rather than attempt to provide a systematic review of the "new" economics of information.

What are the problems addressed in the economics of information? On the positive level of analysis we are interested in the effects of differing amounts of information, and differing inter-personal distributions thereof, upon economic activities -- including, but not limited to, specifically informational activities such as research, dissemination of knowledge for a price or gratuitously, monitoring and detection, etc.) Under this heading: what are the goals of and constraints upon individual behavior in contexts where the emergence or differential possession of information is significant? How do markets function in these circumstances (including the market for information itself), and what can be said about existence of equilibrium? Turning to normative discussions, what do the peculiarities of information-involved economic activities (e.g., problems of defining property rights, externalities, actions of individuals under disparate beliefs) imply for market efficiency and for policy issues such as those connected with copyright and patent, regulation of insider trading and speculation, and the resources devoted to advertising?

In the modern economics of uncertainty individuals choose acts while Nature chooses states of the world. Assigning a consequence function to the interaction of the two choices, a <u>utility function</u> to consequences, and a <u>probability function</u> to states, the individual selects that act which maximizes expected utility. The economics of uncertainty is to the economics of information as the theory of statistical inference is to statistical decision theory. In each case the former subject contemplates only <u>terminal</u> actions; the latter considers also the "non-terminal" option of acquiring additional information to improve one's probability estimates. But the economics of information is more general than statistical decision theory in a number of respects. First, it takes into account not only the possibility of acquiring evidence from sampling experiments, but also by purchase or other social interactions. Second, it considers also the opportunities made available to the individual by the prospect of transmitting or disseminating to others the information in his possession, or by his anticipation of future emergence of private or public information. And, of course, the economics of information is concerned most essentially with the problem of <u>market equilibrium</u> as well as with private <u>optimization</u> on the part of the decision-maker.

I. <u>Informational Decision Analysis</u>

The first topic to be considered here is, however, solely on the level of private action: by "informational decision analysis" we mean optimizing the receipt and use of informational inputs. Once given sample evidence (news, messages) a decision-maker would employ Bayes' Theorem to convert his prior beliefs into posterior probabilities to be entered into his expected-utility calculation for selection of optimal action. A more general problem than the use of <u>given</u> evidence is the question of investing in <u>a set of possible messages</u> -- an "information service" -- not knowing in advance, of course, which member of the set will actually be received (Jacob Marschak [1968, 1971]).[1] For each possible distinct message, the conditional expected utility gain associated with the switch in optimal action (due to the Bayesian revision of probabilities) can be calculated -- allowing, of course, for the cost of the message service. Consistency with prior beliefs as to states determines the assignment of subjective prior probabilities to each possible message generated by the information service. The overall value of the information service is then the probability-weighted sum of the conditional expected utility gains due to the different possible messages.

The decision whether or not to buy an information service, or to choose one service over another, generally depends upon: (1) the cost of the service; (2) the decision-maker's particular endowment position as well as his consequence function, utility function, and prior beliefs; and, most relevant for our purposes here, (3) the characteristics of the message set to be provided.

It would be very convenient if a measure of "informativeness" could be calculated from the characteristics of the message set, such that a "more informative" information service would be preferred (cost being equal) independently of the decision-maker's particular situation. There was some initial hope of using the "entropy" measure of communication theory (see Claude Shannon) for this purpose. "Entropy" in the informational sense is the expected number of binary messages needed to communicate the output of an information service. This is indeed a measure of the amount of information, somewhat analogous to ton-miles as a measure of amount of transportation. However, Kenneth J. Arrow (1971) and Marschak (1973) have shown that only in a special case does the entropy measure effectively scale the value of information. For example, other things equal an information service with a given entropy measure will be more valuable (relative to its cost) to an individual with higher dispersion of prior beliefs, or with a utility function displaying higher risk-aversion. With constant relative risk aversion (CRRA) utility functions, the value of an information service increases or decreases with wealth according as CRRA is less than or greater than unity.

More generally, only partial orderings of the "informativeness" of information services can be provided. The basic idea (Jacob Marschak and Koichi Miyasawa) is that one information service is definitely more valuable than another if the second can be regarded as a "garbling" of the first. Garbling consists of a revision of probabilities, such as might be generated by an imperfect receiver-transmitter, wherein each original message has some probability of being converted into a different member of the original message set. An important special case of garbling (see Roy Radner, Oliver Hart) consists of the obliteration of distinctions: two or more messages in the original set are converted into one. But if one message set is not a garbled version of a second, or vice versa, the two cannot be ordered independently of the particular circumstances of the decision-maker.

So far we have considered messages taking the form of sample <u>evidence</u>. Another possible type of informational input is the <u>opinion</u> (probability beliefs) of another party -- e.g., of an expert. In general, a decision-maker should take some account of the opinions of all other parties in whom he places credence ("valuable opinion," in the terminology of Steven Shavell.) Two questions arise here: (1) how to provide an incentive structure that induces others to reveal their true beliefs, and (2) how to revise one's own opinion in response.

With regard to the first question, the problem is to find a "probability scoring rule" to induce sincerity on the part of the expert. Where both forecaster and client have linear utilities in income (no risk-aversion), giving the former a proportionate share of the latter's payoff will suffice. Scoring rules that are independent of the client's particular decision problem include logarithmic, quadratic, and spherical rules. In general, each such rule will be appropriate for a certain class of client payoff function (see Judea Pearl). Given these opinions, the decision-maker can perform a Bayesian analysis based on a joint probability distribution summarizing his prior beliefs as to the accuracy of his own and others' opinions (Peter A. Morris).

Informational decision analysis becomes more complex when it concerns not a single decision-maker, with or without hired experts, but rather a group of individuals jointly responsible for some common decision (see Howard Raiffa, Ch. 8, Pt. 2). Even assuming that members of the group have agreed upon a constitutional rule (e.g., unanimity), new problems stem from possible conflicts of interest (differences in utilities) or conflicts of opinion (differences in beliefs) as to group outcomes.

Where there are differences of belief, without conflicts of interest, disagreement as to terminal action tends to lead the group to invest "excessively" in information -- from the vantage-point of an impartial observer. For, each member believes that the incoming evidence will likely support his position. On the other hand, where agreement on terminal action masks compensating disagreements (as to multiple contingencies), the group tends to concur in not seeking information where the impartial observer would do so.

If there are conflicts of interest as well as lack of consensus, the redistributive effect of information becomes an important determinant. The group tends to agree to acquire information, apart from any common interest or even at a collective disadvantage, once each member has staked out a position whereby he expects to benefit at the expense of the others -- as by a wager. (On the other hand, the group tends to reject information, even if useful and free, that would arrive before individuals can stake out such positions.) Note that even if there were no initial conflicts of interest, wagering possibilities convert mere conflicts of opinion into conflicts of interest!

The group interest in attaining consensus without excessive informational investments may therefore be opposed by the private interests in not doing so. Granted agreement to seek consensus, conditions under which this may be achieved have been examined by Richard Zeckhauser (1968), Robert J. Aumann, and Morris H. DeGroot.

II. Emergent Public Information

The previous section considered only the problem of optimization (and that, only with regard to prospective information inputs). The emphasis henceforth will be upon the interaction of individuals' optimized information-involved decisions (including dissemination as well as acquisition) with conditions of market equilibrium.

The simplest model to analyze is that of emergent public information -- where all economic agents know that public messages (news) about one or more economic parameters will become available, without cost, at some later date. Decision-makers' choices, with regard either to productive transformations or market portfolios, must balance the advantages of early commitment versus flexibility.

On the level of optimization decisions such models have been involved in recent discussions of "option value" (see Burton A, Weisbrod, Charles J. Cichetti and A. Myrich Freeman, and Kenneth J. Arrow and Anthony C. Fisher). The aim of these authors was to rationalize the choice of a lower-yielding investment alternative to higher-yielding ones that irreversibly transform the environment. In particular, Claude Henry (1974a,b) showed how "option value" depends upon the interaction of two determining conditions -- irreversibility and emergent information.

Exactly the same issues are involved in determining the value of <u>liquidity</u> (see Marschak [1949] and Hirshleifer [1972]). "Demand for liquidity," interpreted as willingness to hold short-term assets even at a rate-of-return disadvantage relative to long-terms, also results from the combination of (1) anticipation of emergent information, and (2) a degree of physical irreversibility of long-term investments (reflected, in somewhat diluted form, even in purely financial instruments).

One puzzle has arisen in this connection. Early discussions by John R. Hicks and James Tobin explained "liquidity preference" primarily in terms of <u>risk-aversion</u> rather than of information emergence and irreversibility. In Tobin's analysis, "liquidity preference" is epitomized by the choice of safe but low-yielding investments (especially <u>money</u>) over higher-yielding but risky ones. In terms of this model, Takeshi Murota showed that the more the <u>prior</u> information (the better the knowledge as to the net return from the risky asset), the <u>less</u> the liquidity preference.

Thus, liquid (flexible) investments are complementary to <u>emergent</u> information, but are a substitute for <u>prior</u> information. In the absence of anticipations of emergent information, risk-aversion is the predominant motive for holding safe investments -- and thereby flexible ones, since flexibility and safety are correlated. But with emergent information, Robert Jones and Joseph Ostroy have shown that risk-aversion plays only a minor role in the demand for liquidity. Since flexibility augments opportunities, rather than merely providing safety, even risk-neutral and risk-preferring individuals tend to prefer liquid assets.[2] On somewhat parallel grounds, Benjamin Eden has pointed out that a gamble with deferred information as to outcome (e.g., stock purchase) is much less flexible than a gamble with immediate outcome (e.g., casino bet) -- hence seeming risk-aversion reflected in stock market returns need not be inconsistent with risk-preference for casino gambles.

Another phenomenon associated with emergent information is speculation. The anticipation of news as to aggregate commodity endowments (e.g., big crop or small) divides trading into a prior round and a posterior round, with inter-related price equilibria; speculation consists of taking actions designed to take advantage of the price transition.

John M. Keynes and Hicks regarded speculation as a process for the transfer of price risks. In their view speculators are characterized not by any special knowledge or beliefs but simply by greater tolerance of risk in comparison with their trading partners -- the more risk-averse "hedgers." The key flaw in this reasoning is that price risk is necessarily associated with (and indeed the resultant of) a more fundamental quantity risk. When the interactions of price risks and quantity risks are taken into account, it has been shown that differences in risk-tolerance alone do not explain speculator behavior (Hirshleifer 1975). Rather, essentially as argued by Holbrook Working, speculation is fundamentally a consequence of differences

<u>of belief</u>. The social function of speculation then is not the transfer of price risks but improvement in the accuracy with which present "futures" prices reflect the opinions of informed traders in the market.

The achievement of this function is however constrained by incompleteness of markets -- in particular, absence of state-contingent contracts. But there is a trade-off between completeness of markets in any single round and the number of sequential rounds of trading made possible by repeated injections of information (see Jacques Drèze, Mark E. Rubinstein).

An interesting case is that in which information arrives without any prior trading -- i.e., when individuals are still at their endowment positions. A number of authors have shown that, in such a situation, the prospect of emergent information tends to make people <u>worse off</u>: the resultant price revision imposes an undesired redistributive risk upon the intrinsic endowment risk (Hirshleifer 1971, John Marshall, Zeckhauser 1972). Echoing a point made earlier about group decisions, because of discordant beliefs each separate trader may regard himself as prospectively profiting from informational emergence that necessarily injures traders in the aggregate (Marshall, Hassouna Moussa and Takeshi Murota).

III. <u>Asymmetrical Information Endowments</u>

In market trading of commodities whose quality is not costlessly manifest, the seller commonly -- though not always -- has an informational advantage. Consider, following George Akerlof, the extreme case where direct authentication of sellers' quality claims is so costly that all products on the market are effectively indistinguishable to buyers. Supposing that the distribution of quality levels in the commodity population is <u>fixed</u>, it might be thought that the equilibrium price would reflect the average level of quality. But the owners of the higher-quality units will have higher reservation prices and will therefore tend to withdraw from the market ("adverse selection"). However, adverse selection does not necessarily dictate a corner equilibrium with only lowest-quality goods being exchanged at a correspondingly low price. For, the mutual advantage of trade tends to bring some higher-quality units into the market, leading to an interior equilibrium of price and quantity (Zeckhauser, 1968).

The problems are compounded if owners can save costs by degrading higher-quality into minimum-quality units before placing them on the market. (This is one of the meanings of "moral hazard" in insurance jargon.) Then, if buyers lack all discriminatory power, no price above that reflecting the minimum quality level can be sustained.

A variety of direct ways of counteracting the adverse-selection and moral-hazard problems have been described: among them are money-back guarantees, brand names and reputation, professionalism, and the marketing of information services (see Akerlof, Arrow 1963, Michael R. Darby and Edi Karni). Apart from the costs of these activities, there is a life-cycle problem: if it pays a "young" firm to invest in assuring customers that its products are high-quality, it may pay an "old" firm ultimately to depreciate that investment by fooling its last customers.

Recent advances have improved our understanding of indirect ways of communicating information about quality, in which sellers engage in activity that would not be rational except where a quality advantage exists ("signalling") and buyers draw the appropriate conclusions ("screening").

Phillip Nelson (1974, 1975) pointed out that advertising tends to be more rational for producers of higher-quality goods, in contexts where repeat purchases are a significant consideration. (Absent the anticipation of repeat purchases, producers of lower-quality products could profitably mimic the promotional policies of higher-quality producers.) Quite apart from any informational content of such promotion, the essential message being conveyed is that the product is worth advertising.

Nelson's signalling via advertising is based on the premise the marginal benefit of promotional expenditures is greater for the higher-quality sellers. A. Michael Spence and Joseph E. Stiglitz have proposed models in which the marginal cost of signalling is lower for the higher-quality sellers. In particular, in seeking jobs for which productivity is difficult to determine, those workers who are more productive may signal this fact by accumulating more educational credentials -- if, as is plausible, they can do so more easily than lower-quality workers.

There are some difficult questions about equilibrium in screening models.[3] An externality generally exists, in that each seller is impelled to greater signalling investment by any signalling on the part of those lower on the quality spectrum -- from whom he wants to be distinguished. John Riley (1976) has shown that a "reactive equilibrium" concept leads to a solution in which those lowest on the spectrum do not signal, and receive the same wage as if their productivity could be costlessly observed.

How the social costs of the communication effected by signalling compare with alternatives (such as direct quality testing, or the enforcement of contracts with payment conditional upon ultimate determination of quality), and whether signalling may remain viable even if involving greater social costs than these alternatives, are questions still subject to debate.

IV. The Economics of Research

Traditionally, it has been argued that incentives for the production of information via research are inadequate -- essentially because of the legal and practical impossibility of writing and enforcing patents that reward the inventor with the full social gain due to his innovation (Arrow, 1962; Machlup). But there are arguments on the other side. Applying the fishing model of H. Scott Gordon, Yoram Barzel showed that, in the absence of property rights to undiscovered ideas (unhooked fish), there tends to be an excessive level of research. Eugene F. Fama and Arthur B. Laffer and Hirshleifer (1971) pointed out that the prospect of price revisions, consequent upon the dissemination of the information initially in the possession of the discoverer, opens up prospects for speculative profits -- constituting a source of remuneration independent of the social gain flowing from the new information. In principle, therefore, with both patent protection and speculative profit an excessive level of investment in research might be induced.

This latter point has been reviewed by Charles B. Blankart. Suppose the invention reduces cost of production for a product. Then the prospects of speculative gain depend upon the supply and demand elasticities. With horizontal demand, for example, no price revision will take place -- ruling out speculative gain on the commodity. Overcompensation of inventors, in this model, occurs only with relatively inelastic demand and elastic supply. (However, speculation on substitute or complementary commodities remains a possible source of additional gain.)

A number of other writers have questioned the ability to realize speculative profit from prior information. If uninformed traders can <u>monitor</u>

the trading behavior of the innovator, the latter may only be able to trade along an offer curve that sharply constrains the possible speculative gain (Marshall).

Even without monitoring the behavior of the innovator as an identified individual, uninformed traders might be able to infer the content of the information from the movement of price itself (Sanford J. Grossman and Stiglitz, Jerry Green, and Richard E. Kihlstrom and Leonard J. Mirman). This would tend to occur if research takes the form of forecasting randomly recurring events, all traders being aware of the equilibrium price vectors conditional upon the state of the world. Then the slightest attempt to exploit acquired information will initiate a price movement that will reveal the true state to all -- causing prices to jump immediately to the corresponding equilibrium. With sufficiently hair-trigger reaction functions on the part of the uninformed, it will be impossible for the informed to profit.

As in the case of signalling models there is a market externality here tending to break down equilibrium: if none are informed there is potential profit in becoming informed, yet if anyone invests in information and trades accordingly he loses relative to those not having invested. The analog of the "reactive equilibrium" concept here would evidently be the corner solution with no informational investments. However, in contrast with the signalling case, an interior solution can be obtained by introducing noise or lags: if only imperfect information about the state of nature can be inferred by observing prices, or if the informed individual can make his commitments before the uninformed can fully react, there will tend to be an equilibrium fraction of traders who choose to become informed.

V. "Informational Efficiency"

In the Arrow-Debreu world of complete information about traded commodities and competitive markets for all contingent claims, market equilibrium is efficient in the sense that an omniscient observer would not be able to reallocate resources to the advantage of all agents. However, if information is costly, and as a result incomplete, it is hardly surprising that markets no longer have this same efficiency property. This observation does not, however, rule out the possibility that markets may be "efficient" in some narrower sense. For example, in the stock market model developed by Peter A. Diamond, markets are efficient with respect to a restricted set of omnisciently planned allocations.

Another restricted notion of efficiency has been the subject of considerable attention in the finance literature. A market is said to be "informationally efficient" if it is one "in which prices always fully reflect available information" (Fama, p. 383).

Unfortunately, the meaning of the term "fully reflect" has proved elusive. Rubinstein has argued that new public information is fully reflected in prices only if the latter adjust in such a way that, upon arrival of the information, traders have no incentive to change portfolios. But if individuals begin with heterogeneous beliefs they will almost certainly wish to adjust their portfolios. That is to say, prices almost never fully reflect public information!

If individuals begin with homogeneous beliefs but differ in their costs of processing (interpreting) the new information, they will, in general, again end up with heterogeneous beliefs. Suppose that there are low-cost and high-cost processers of public information. If the latter choose to ignore the new information because the processing cost outweighs the benefits, they will again wish to adjust their portfolios unless the revised offer curves of the informed traders are such that asset prices remain constant. Once again prices do not fully reflect available information in the Rubinstein sense.

In contrast, Grossman and Stiglitz have interpreted the "efficient market hypothesis" to mean that prices fully convey (private) information. In terms of our illustration, efficiency then requires that the high-cost processers are able to infer (from the price changes) the content of the evidence processed by the low-cost group. As we have seen in the previous section, under these conditions the market for private information is not viable.

The underlying problem here, in our opinion, is confusion between "efficiency" as used to characterize equilibrium configurations and as applied to disequilibrium processes. Consider an analogous problem with regard to "profit." In an efficient competitive equilibrium, there are no competitive profit opportunities -- and yet, this outcome is the end-result of a process in which profit provides the motivating force. Whether competitive profit-seeking takes place at the ideal rate, and is therefore dynamically efficient, is quite another question, to answer which we as yet lack adequate tools. In its recent usage, "informational efficiency" means essentially that there is no way of making money from informational activities. Since information-involved activities (information seeking, processing, disseminating, etc.) by their very success tend, like profit-seeking activities, to eliminate their own raison d'etre, it is certainly true that in equilibrium there will be no way of making money via such activities. But this says nothing whatsoever about the dynamically optimal level of informational activities -- which are, of their very nature, disequilibrium processes.

FOOTNOTES

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[1] In a somewhat special context, this becomes the problem of "optimal search" recently reviewed by Steven A. Lippman and John J. McCall.

[2] See also Thomas Marschak and Richard R. Nelson.

[3] Recently Michael Rothschild has surveyed the recurring paradox of non-existence in screening and other imperfect information models.

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