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WHERE ARE WE IN THE THEORY OF INFORMATION?

by

J. Hirshleifer

University of California, Los Angeles

Los Angeles, California 90024

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WHERE ARE WE IN THE THEORY OF INFORMATION?

J. Hirshleifer *

As the "knowledge industry" booms in the world of affairs (F. Machlup 1962, J. Marschak 1968), the economics of information has been blooming with striking and novel ideas in the intellectual realm. The rate of advance is suggested by the remarkable number of papers I will be citing that have not yet seen formal publication.

To keep the topic within bounds, I must cut drastically. First, I limit myself to theoretical innovations. Even so, many topics must be omitted, among them: (1) The informational presuppositions underlying analytical concepts like the demand curve, short-run versus long-run cost functions, and imperfect competition. (2) The crucial role of information in bargaining and game theory. (3) Keynesian disequilibrium, in macrotheory, as an informational disfunction of the decentralized market economy. (4) Interpretations of unemployment as specialization in search for better opportunities. (5) Money as an institution economizing on knowledge that would otherwise be necessary to complete transaction chains. (6) The prospect of emergent information as determinant of demand for "liquidity" and of speculative behavior. (7) Adaptive expectations and other learning models. (8) Efficient flows of information within multi-person organizations. I must set aside fascinating and important developments in these areas to concentrate upon my central theme -- the microeconomics of information proper. Or somewhat more explicitly: THE PRODUCTION, DISSEMINATION, AND MANIPULATION OF INFORMATION IN A MARKET CONTEXT.

The microeconomics of information in this narrower sense is an outgrowth of the economic theory of uncertainty. Uncertainty is summarized by the dispersion of individuals' subjective probability (or belief) distributions over possible states of the world. Information, for our purposes, consists of events tending to change these probability distributions. A rather different concept of "information" is employed in communications and statistical theory, according to which a dispersed probability distribution is called less "informative" than a concentrated one (for certain applications, see H. Theil). This latter concept uses the term "information" merely as a negative measure of uncertainty. But it is changes in belief distributions -- a process, not a condition -- that constitute here the essence of information. Note that the economics of information is active where the economics of uncertainty is passive. Mere adaptation to a given state of ignorance via optimal "terminal" action is still in the realm of the economics of uncertainty; in going beyond this to consider the alternative of gathering more evidence prior to terminal action, we enter the domain of the economics of information.

I. INFORMATION-INVOLVED BEHAVIORS; CATEGORIES OF INFORMATION

The distinction between passive and active adaptations to the fact of uncertainty is a familiar one in the theory of statistical decision, which falls naturally into the two divisions of: (a) Criteria for action on given sample evidence, versus (b) Design of experiments for the generation of additional evidence. But where the statistician considers only acquisition of information by experiment, we want to examine the wider opportunities that arise for acquiring and using information in a market context.

Table 1 classifies behavior modes for possessors and for seekers of economically valuable information. The possessor can in general benefit simply by

private use of the information for his own productive or consumptive decisions. But in a market context it might also be possible for him to profit from sale of the information to others. The information-seeker might correspondingly find it advantageous to produce socially "new" information by direct inquiry of Nature (research) or to purchase "second hand" information in the market. Viewed as a tradable commodity, information has (as we shall see) a number of special features. The most novel aspects of the economics of information stem, however, from the behavior possibilities indicated by the third line of Table 1. In the market process information can be regarded as "pulled" from the possessor by sale, i.e., by payment of an explicit price. But what is surprising, the possessor may find it preferable to give away this valuable commodity, to disseminate it without pull of compensation. Indeed it may be highly profitable for him to incur costs so as to gratuitously "push" information to potential recipients! As for the information-seeker, his knowing that the possessors are so motivated may lead to adoption of a monitoring or listening mode of learning behavior (J. Marshall).

Standing somewhat apart in the Table, but a crucial element whenever information is to be disseminated (whether gratuitously or by sale), is the possibility of deception -- leading to the counter-activities of evaluation on the part of the information-seeker and authentication on the part of the disseminator.

TABLE 1: INFORMATION-INVOLVED MODES OF BEHAVIOR

<u>Possessor of information</u>	<u>Seeker of information</u>
1. Private Use	1. Production (research)
2. Sale	2. Purchase ("pulling")
3. Gratuitous dissemination ("pushing")	3. Monitoring
4. Deception -- authentication	4. Evaluation

TABLE 2: ECONOMICALLY SIGNIFICANT INFORMATION ATTRIBUTES

1. Certainty
2. Diffusion
3. Applicability: particular vs. general
4. Content: Environmental vs. behavioral
Tastes, endowments, technology, vs. market parameters
5. Decision-relevance

Listed in Table 2 are a number of attributes affecting the value of information to potential users or producers. Certainty refers to the degree of concentration of posterior belief distributions dictated by the information; fully certain information assigns 100% probability to a single value of the variable being predicted. The extent of Diffusion will obviously affect the scarcity value of information. Applicability is, at one extreme, particular to a single economic agent -- as when I learn of oil under my land. A new process for extracting oil more cheaply from everyone's land would be of general applicability. The Content of information may be subclassified in a variety of ways. One distinction commonly made is between information about the physical environment versus information about the strategies or behavior of other individuals; this is relevant for considerations of Pareto-optimality (R. Radner). Another useful classification runs in terms of the elements of choice-theoretic structures in economics: tastes, endowments (resources), technology (production functions), and market characteristics (price or quality of traded goods). The aspect of Decision-relevance has been brought forward (Marschak 1964, Marschak and K. Miyasawa) as a corrective to attempts to quantify economically relevant information by the "bit" measure of communications theory. "Coarseness" of the message delivered would seem, for example, to be a negative feature. And

yet a coarse message properly in tune with the decision to be made ("This stock will rise!") may be much more valuable than a more precise message out of tune ("This stock will move exactly 10 points, but up or down with equal probability!")

Time and space fortunately preclude systematic coverage of the full range of behaviors in Table 1 over the information attributes in Table 2. As it happens, a review of the existing literature may be divided into two distinct branches. In the first, individuals are assumed subject to technological uncertainty only. They are unsure about, and therefore interested in information concerning, only their resource endowments and/or productive opportunities. Analysts here generally have assumed perfect markets (except, possibly, for the market for information itself) -- so that an equilibrium integrating all supply-demand offers is instantaneously and costlessly attained. In the second division of the literature technological uncertainty is assumed away; there is market uncertainty instead. Each individual is supposed to be fully certain about his own endowment and productive opportunities, but only imperfectly informed about the supply-demand offers of others. The two areas are reviewed in the sections that follow.

II. TECHNOLOGICAL INFORMATION: THE UNDERINVESTMENT ISSUE

A. General Information and Patents

Patents permit the conversion of certain types of information (ordinarily, production-function information of general applicability) into legally recognized property. The traditional position has been that while patent royalty fees hinder the optimal utilization of information once produced, lack of appropriability would otherwise lead to underinvestment in new technological ideas (Machlup, 1968). K.J. Arrow (1962) has developed this line of thought further, maintaining that there would be underproduction of ideas even with a patent

system because: (1) invention is risky, and all risky activities are under-exploited for lack of complete conditional-contract markets; (2) appropriability is imperfect, since patent protection is only partially effective; and (3) royalty schemes do not generally capture all the benefits for the inventor.

This seems quite convincing, but recent contributions show that there are also considerations cutting in the opposite direction. Y. Barzel has argued that undiscovered ideas are like fish in the sea, subject to the rule of capture. Since the patent right goes to the first in possession, with perfect patents competitive invention would be biased toward prematurity. The rule of capture leads to too many too small fish being caught! On quite another ground, J. Hirshleifer (1971) has shown that the standard analysis entirely ignores the profit possibilities implicit in the bottom line of Table 1 -- the "pushing" of information. The inventor, first in the know, might be in a position to predict and therefore speculate upon price revaluations ensuing from the publicizing of his information.¹ The Hall process, for example, increased the value of bauxite ores. Note that the profit opportunities here dictate the widest dissemination of the information; the speculative "pushing" motive, in contrast with the sale motive that the patent institution facilitates, furthers both the utilization and the production of information. As an additional point, where there are differences of belief incentives exist for cooperative investment in information acquisition that may easily exceed the social value thereof. For, each individual feels that the outcome of the investigation will tend to validate his own prior beliefs and speculative commitments. Horse racing is a clear example of cooperative overinvestment in information -- the stock market, perhaps, not quite so clear a one.

B. Particular Information and the Disclosure Problem

F. A. Hayek's pioneering 1945 article emphasized the importance of "knowledge of particular circumstances of time and place" (information of particular applicability) as opposed to "scientific knowledge" (information of general applicability). Hayek went on to argue that a centralized economy would find it difficult to communicate particular information to decision-making points -- whereas, in a market economy, all the relevant aspects of such information are efficiently disseminated via the price system.

Interestingly, Hayek speaks only of the use of information -- not its production. While it is plausible to argue that individuals are appropriately motivated in a market economy to generate self-regarding information and also are generally well-placed for doing so, it may be that other parties have a comparative advantage in its actual production. But the motivation for outsiders to produce particular information about others for sale (e.g., if I have a way of finding out whether there is oil under your land) is impaired by the unavoidable monopsony on the buying side. And attempts to profit from "pushing" the information will not work very well, since trying to take the requisite speculative position (buy up the under-valued property) will signal the content of the information.

Matters appear in a somewhat different light, however, if we consider information particular not to atomic individuals but to publicly-held corporations. Here the dispersed universe of actual and potential owners of securities constitutes an impersonal market for sale of information about particular firms. And indeed security analysis is a thriving business. Furthermore, the securities markets themselves provide a particularly efficient medium for achieving speculative gains from the acquisition and subsequent dissemination of particular information.

Information generation about particular firms has been studied by E. F. Fama and A. B. Laffer. They argue that there will be waste of resources in information production motivated by the prospect of speculative trading in the corporation's stock (or, at one remove, by the prospect of sale to others who will use the information for that purpose). For, the trading will be merely redistributive in impact. The information may also be of value for improving productive allocations, but there will remain a private motivation for expending resources beyond the level warranted by anticipated productive improvements. (But it should be recalled that without the speculative motive the intrinsic monopsony on the purchasing side would deter efficient outside producers of particular information, so the net balance remains unclear.)

The potential conflict of interest between corporate owners and managers has important implications for the acquisition and dissemination of information. H. G. Manne argues that managerial ("insider") trading in the corporation's stock provides socially useful compensation for entrepreneurial innovation, and concludes that "disclosure laws" limiting such trading are unwise. But trading profits stem from superior information, whether about favorable or unfavorable developments. Thus, insider trading can reward unexpectedly bad managerial performance just as handsomely as good performance; all the insider need do is sell short on the basis of prior knowledge of his own mistakes. Second, the previously discussed overinvestment in information comes up once more -- in especially strong form. Insiders are by definition well-placed to secure information, and may even be able to use corporate funds (rather than their own) to cover the costs of doing so. As an alternative to higher salaries, then, this mode of remuneration of management entails serious inefficiencies.

C. Transferability of Information

One of the key themes of the analysis to this point is that if information were perfectly transferable (either by sale or by pushing), it would be "over-produced" (but see H. Demsetz). The reason is that changes in probability beliefs (and therefore in market prices) lead to wealth redistributions as well as to productive-consumptive adaptations. The sum of gains from the adaptations represents the social value of the information, and is the maximum that can efficiently be paid to cover the costs of producing it. But while the net social value of the redistributions is zero, individuals would obviously be willing to pay to be on the winning side of the shuffle. The sum of the two classes of potential payments would overcompensate the information producer.

Limited transferability is a countervailing consideration. The first problem is that of authenticity: a seller always claims to be telling the truth, but how is a buyer to know? Sometimes authenticity is manifest in the information itself ("Behold!"), or can be made manifest at some cost. Alternatively, authenticity may be conveyed by guarantees or by other techniques to be discussed below. Authenticity being assumed, a number of other elements entering into marketability have been considered by Y. Noguchi. Even with patent protection, it must be possible to detect unauthorized use and to identify the user. Unpatented information is safeguarded by secrecy, which is always compromised by sale. The key problem for the existence of a market in such information is the prevention of unauthorized re-sale. Fama and Laffer, in their paper, assumed completely effective protection against such re-sale; Noguchi, on the other hand, argues that re-sale prohibition can never be effective. The truth, naturally, is somewhere in between. Noguchi points to one other factor that might sometime make possible a market even in the absence of re-sale prohibition: if scarcity

value falls off sufficiently sharply with increased diffusion, it may be irrational for any member of the club of original purchasers to cheat by re-sale.

III MARKET INFORMATION²

The literature dealing with information about market parameters -- more specifically, information about the terms on which potential trading partners are willing to do business -- assumes away any uncertainty about technological and other exogenous features of the economic problem. Information is not wanted here to provide a better basis for the individual's own supply-demand offers, but rather solely to permit taking advantage of the offers of others. Nevertheless, the logical categories of Tables 1 and 2 apply. Information about trading partners, like technological information, can be produced or sold or "pushed". And the difficulty of marketing or otherwise disseminating trading-partner information remains essentially the same as for technological information.

The analysis of market information took a "great leap forward" with the pathbreaking articles of our Chairman G. Stigler (1961, 1962). These papers spelled out and partially solved some of the major questions under this heading, including: (1) the nature and extent of search and advertising behavior (the latter an instance of "pushing" information), and (2) equilibrium in a market with continuing search and advertising. Search and advertising are complementary informational processes. The searcher locates specific offers; the advertiser "pushes" the fact of his existence and, possibly, some details about his terms for dealing. For brevity, I assume in this discussion that buyers search while sellers (or some sellers) advertise -- though in general there will be some of each activity on either side of the market.

A. Information about Price

In the analysis of price information, as opposed to quality or brand

information, it is generally assumed that authenticity is manifest -- even though deceptive ways of quoting price are not unknown in the world of affairs. This simplification, together with the measurability of price, has permitted rigorous mathematical solutions of some outstanding questions.

Rational price search behavior (mathematically, the optimum stopping rule) has been analyzed by a number of authors -- including J. J. McCall, J. L. Gastwirth, and L. G. Telser. Stigler (1961) had originally assumed that the searcher would investigate a sample of predetermined size. The later authors showed that a sequential process is generally superior; the optimal policy is to accept an offer if the terms are superior to a predetermined reservation price. The reservation price itself may be a function of the earlier observations, if these are informative (i.e., if the distribution of price offers is not known a priori). And if the searching takes time, the reservation strategy should take account of the fact that both the returns and the opportunity costs of search are influenced by temporal factors (A. A. Alchian and R. Gronau). The returns from search are also affected by the importance of the commodity in the budget, by the durability of the information gained, and by the shape of the a priori probability distribution. The costs of search depend upon the distance of sellers from the buyer and from each other (i.e., their locational concentration) and the extent to which they have been identified and their offers made visible by advertising or other means.

The seller's advertising decision is bound up with his reciprocal anticipations of buyer search behavior, his standing in the price distribution (assuming he knows it), and the advertising effort of competitors. The distinctiveness of the commodity, the rarity of buyers, and the efficiency of the communications media are all involved. Finally, middlemen (brokers) may emerge

who specialize in the acquisition of market information and its sale to traders on one or both sides of the market.

The second major problem under this heading is market equilibrium, and its consistency with continuing search/advertising activity. The difficulty is that search and advertising appear to lead toward a unique price equilibrium rather than a distribution of prices. Stubbornly high-priced sellers will over time lose customers, and low-priced sellers will become swamped with clients -- leading in both cases to a corrective movement of price offers. As this correction takes place the gains from search and advertising dwindle. So these processes seem to be self-limiting, consistent with transition toward but not achievement of equilibrium.

Of course, the exogenous conditions determining demand and supply are ever-changing; as Stigler points out, change maintains price dispersion and, therefore, the rationale for search and advertising. This amounts to saying that we are always in transit to, never at equilibrium. But if the exogenous changes can be regarded as drawings from a fixed probability distribution, the economic system may converge toward a statistical equilibrium containing price dispersion and associated search/advertising behavior (J. R. Green).

Stigler's original paper also mentions, however, endogenous factors that tend to preserve price dispersion -- mobility and forgetting. Mobility of buyers and sellers into and out of the market (for example, in an intergenerational life-cycle model) will provide a continuing demand for the informational processes of search and advertising. Forgetting achieves the same result by destroying information; forgetting is akin to a mutation probability offsetting the adaptive directive effect of search.

Finally, M. Rothschild and M. Yaari (reported in Rothschild) have developed

a model in which sellers engage in experimental price variation while buyers are simultaneously searching. The combination results in sellers and buyers never becoming perfectly informed, so that price dispersion and search behavior persist.

B. Information about Quality

Uncertainty about quality poses an intrinsically more difficult problem than uncertainty about price. There are two main reasons. First, quality may be multi-dimensional, unquantifiable in some respects, and may contain an irreducible subjective element. Second, the authenticity of the claims made by sellers now becomes a most serious question for market participants.

In the typical situation in the literature, information endowments are asymmetrical: specifically, let us assume that the seller knows the quality of the product but the buyer does not. G. A. Akerlof has shown that the informational asymmetry may lead to what is called "adverse selection" in insurance jargon. Suppose that buyers can only judge quality by the average level in the market. Then sellers with inferior products are encouraged to offer them for sale -- while those with superior products are correspondingly discouraged. A process of progressive deterioration of the market's quality level tends to take place; in some cases there will be a stopping-point with a positive level of transactions, but in others the market may be non-viable. Furthermore, there is a parallel and reinforcing process that corresponds to "moral hazard" in insurance jargon (Arrow 1963); this refers to the temptation to sellers to deliberately degrade the quality of the product in response to buyer ignorance.

Countervailing institutions tend to emerge, establishing distinctiveness and responsibility through brand names. Devices employed include informative advertising, guarantees, "signalling", and independent information producers.

Informative advertising, an elusive though perhaps not so rare category, convinces by its content -- e.g., by citing known or verifiable facts and drawing valid inferences from arguments. Guarantees lend conviction because the seller makes himself vulnerable to penalty should the claim prove incorrect.

"Signalling", a concept introduced by M. Spence, is a kind of implicit guarantee; the seller engages in some ancillary activity that would be irrational were his claims not correct. In the example used by Spence higher-quality workers signal by acquiring education (even if education does not contribute to productivity) -- on the hypothesis that employers know that higher-quality workers can more easily or cheaply undergo the educational ordeal. Independent information producers (including both for-profit concerns and not-for-profit certifying agencies like medical associations) have the same problem of establishing their own brand name before they can be of value to others.

Buyers, of course, will not be entirely incapable of evaluating quality for themselves. P. Nelson (1970) distinguishes two types of consumer investigative behavior: inspection (Nelson uses the less appropriate designation "search") is evaluation that can take place without purchase, experience only after purchase. One or the other process will in any given situation be the cheaper, and commodities can accordingly be classed into inspection goods and experience goods. Nelson maintains that a larger number of brands will tend to be sampled for high-purchase-frequency items and also for inspection goods as against experience goods. Then inspection goods should tend to be more competitively marketed -- monopoly power will be less if consumers sample widely. Reinforcing this is the consideration that elasticity of demand approaches zero during the experimental phase when investigating by experience, since the consumer cannot presume in advance that a higher-priced brand is not correspondingly

higher-quality; this point does not apply to inspection goods, which are not actually purchased in the experimental phase.

Nelson considered the market implications of quality evaluations by buyers. M. R. Darby and E. Karni have examined the effect of buyers' difficulty in evaluating quality upon seller behavior. Unlike Akerlof, they consider a situation in which sellers accept responsibility for quality claims. The temptation to depreciate quality that constituted "moral hazard" for Akerlof becomes "fraud" for Darby and Karni. As in Akerlof's situation, countervailing market arrangements tend to emerge. They include service contracts (the seller in effect commits himself to maintaining a level of service from the good), the client relationship, and of course the implicit guarantee of a brand-name reputation. Note that we have here another illustration of the general problem of authenticating disseminated information.

C. Market-Information Processes and Social Efficiency

It seems plausible, and several authors maintain, that there are favorable externalities in the discovery and dissemination of valid market information, and hence that these activities should be encouraged by public policy. Akerlof has pointed to such an externality where markets are threatened by information disparities (the adverse-selection and moral-hazard problems). Darby and Karni point to the social waste of resources devoted to fraud (while warning that government "protective" activities cannot be assumed to be disinterested either). Arrow (1963) had suggested earlier that there would be underproduction of valid market information, a contention that parallels his arguments about technological information (1962). On the other hand, in the model of Spence even the resources devoted to signalling perfectly authentic information are socially unproductive (although privately remunerative); as in the corresponding contentions of

Hirshleifer and Fama and Laffer for technological information, the gains from better information can sometimes be merely redistributive.

What about advertising regarded as an information-transfer process? I must limit myself to a few points here. First, even short of what Darby and Karni would call fraud, it is evident that resources are being wasted conveying inauthentic information. Nelson (1972), on the other hand, emphasizes consumers' power to police the informative content of advertising, particularly in the case of inspection goods. Even for experience goods, Nelson argues, the fact of advertising itself conveys an assurance of quality. The higher-quality brand will, other things equal, have a comparative advantage in acquiring more customers by advertising -- since it will retain a larger fraction of them on repeat sales. Nelson's argument, in effect, is that advertising is a "signal" in Spence's sense. Finally, because of our limited mental-processing capacities there may well be a congestion effect at work: if, as G. A. Miller says, we can only keep in mind seven things at once (plus or minus two), one good datum may just be driving out another.

FOOTNOTES

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1 See also Hirshleifer (1972).

2 I have made use here of the excellent survey by Rothschild.

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