The Private and Social Value of Information and the Reward to Inventive Activity

By Jack Hirshleifer*

A number of recent papers[1] have dealt with the economics of information in a context in which each individual is fully certain about his own endowment and productive opportunities. In those papers, the individual is imperfectly informed only about his market opportunities, i.e., about the supply-demand offers of *other* individuals. In consequence, costly patterns of search for trading partners replace the traditional assumption of costless exchange.

This paper deals with an entirely different aspect of the economics of information. We here revert to the textbook assumption that markets are perfect and costless. The individual is always fully acquainted with the supply-demand offers of all potential traders, and an equilibrium integrating all individuals' supply-demand offers is attained instantaneously. Individuals are unsure only about the size of their *own* commodity endowments and/or about the returns attainable from their *own* productive investments. They are subject to technological uncertainty rather than market uncertainty.[2]

Technological uncertainty brings immediately to mind the economics of research and invention. The traditional position has been that the excess of the social over the private value of new technological knowledge leads to underinvestment in inventive activity. The main reason is that information, viewed as a product, is only imperfectly appropriable by its discoverer.[3] But this paper will show that there is a hitherto unrecognized force operating in the opposite direction. What has been scarcely appreciated in the literature, if recognized at all, is the *distributive* aspect of access to superior information. It will be seen below how this advantage provides a motivation for the private acquisition and dissemination of technological information that is quite apart from—and may even exist in the absence of—any social usefulness of that information.[4]

I. Foreknowledge Versus Discovery

Within the category of technological (as opposed to market) information, dif-

* Professor of economics, University of California, Los Angeles. This paper is an abbreviation of a report with the same title prepared for Western Management Science Institute, UCLA (1970b). The research at WMSI was supported by the National Science Foundation and the Office of Naval Research. Valuable suggestions have been contributed by Earl Thompson, Jacob Marschak, Ross M. Starr, Benjamin Klein, and Joseph Ostroy.

[1] See S. A. Ozga, George Stigler (1961, 1962), and Armen Alchian.

[2] These two types of uncertainty have been distinguished by a number of authors: see Tjalling Koopmans (pp. 161ff), Peter Diamond, Jacob Marschak (1968b, p. 17).

[3] See Kenneth Arrow (1962, p. 619). The comment by Harold Demsetz is also of interest. On patents as a device to achieve appropriability, see Fritz Machlup.

[4] In connection with policy debates over stock market "insider trading," Henry Manne has discussed the private and social gains attached to the dissemination of corporate information. A very recent article by Eugene F. Fama and Arthur B. Laffer emphasizes the differing motivations of insiders and outsiders for the generation of such information; their analysis, though in a partial-equilibrium context, in some ways parallels the treatment here.

ferent sorts of knowledge are associated with rather different private incentives and social efficiency conditions. This paper concentrates upon a distinction between what will be called foreknowledge on the one hand, and discovery on the other. The type of information represented by foreknowledge is exemplified by ability to successfully predict tomorrow's (or next year's) weather. Here we have a stochastic situation: with particular probabilities the future weather might be hot or cold, rainy or dry, etc. But whatever does actually occur will, in due time, be evident to all; the only aspect of information that may be of advantage is prior knowledge as to what will happen. Discovery, in contrast, is correct recognition of something that possibly already exists, though hidden from view. Examples include the determination of the properties of materials, of physical laws, even of mathematical attributes (e.g., the millionth digit in the decimal expansion of "π"). The essential point is that in such cases Nature will not autonomously reveal the information; only human action can extract it. Foreknowledge information is conceptually simpler to deal with, involving as it does only the value of *priority* in time of superior knowledge; this topic will be taken up first below.

II. Elements of the Economics of Foreknowledge

The analysis of the value of priority of information necessarily involves both temporality and uncertainty. For convenience, the simplest possible paradigm of choice will be employed. Suppose that there exists but a single physical good (corn). It will be assumed, however, that a number of different types of claims may be owned or traded—claims to corn at specified dates and under specified contingencies or "states of Nature."[5] It suffices to consider a particularly simple model in which the present (time 0) is certain, and the future consists of a single date (time 1) at which just one of two alternative states (a or b) will obtain. The marketable commodities of the analysis can be denoted c_0, c_{1a}, and c_{1b}: claims to corn valid at, and only at, the subscripted dates and states.

Each individual will have a utility function governing his preferences *now* for holdings of alternative combinations of these claims. Entering into this function will be his beliefs as to the probabilities π_a and π_b of the two states. It has been shown[6] that, under certain widely accepted assumptions, it is possible to find a cardinal intertemporal function $u(c_0, c_1)$ that (a) measures desirability of alternative *certain* dated consumption sequences and (b) is such that the von Neumann-Morgenstern expected-utility rule can be employed to order preferences among *risky* sequences of time-state claims, according to the formula:

$$(1) \qquad U = \pi_a u(c_0, c_{1a}) + \pi_b u(c_0, c_{1b})$$

This utility function exemplifies the property of "state-independence," i.e., the expected utility is a sum of distinct terms each of which is associated with only one particular state of the world.[7]

The utility function to be used below

[5] The conception of state-claims as commodities stems from the pioneering work of Arrow (1953, 1964). Gerard Debreu (ch. 7) extended Arrow's model to multiple time-periods. The paradigm of choice involving time-state claims has been further developed by other authors, including Karl Borch and Hirshleifer (1965, 1966).

[6] See Jacques Drèze and Franco Modigliani; Hirshleifer (1970a, ch. 8).

[7] *State-independence* is an implication of the von Neumann-Morgenstern postulate sometimes called "irrelevance of nonaffected outcomes"—see Marschak (1968a). The key idea is that when we are dealing with *prospects* which promise to offer one consequence if state a obtains and another if state b obtains, we need not consider any relations of complementarity in preference. For there is never any question of receiving the *combined* consequences attached to the two states; the individual will necessarily receive one to the exclusion of the other.

makes the further specification that $u(c_0, c_1)$ can be written in the special form $v(c_0)+\theta v(c_1)$, where θ is a fixed time-preference parameter characteristic of the individual, and v is a cardinal preference-scaling function for income valid for him at each state and date. The essential additional property underlying this specification may be called time-independence.[8] Given both state-independence and time-independence, the utility function becomes:

$$(2)\quad \begin{aligned} U &= \pi_a(v_0 + \theta v_{1a}) + \pi_b(v_0 + \theta v_{1b}) \\ &= v_0 + \theta(\pi_a v_{1a} + \pi_b v_{1b}) \end{aligned}$$

where v_0 is condensed notation for $v(c_0)$, and v_{1a} and v_{1b} are defined analogously.

The acquisition of information will take the form of warranted revisions in the probability estimates π_a and π_b that enter into preference functions and so guide decisions. In what follows it will be essential to distinguish *private* information (available only to a single individual) from *public* information (available to everyone)—intermediate cases will generally be ignored. It will also be important to keep in mind the distinction between information that is *prior* to, and information that is *posterior* to, the individual consumption-investment decisions that must be made at t=0. Still another distinction is that between *sure* information (as to which future state will obtain) and merely *better* information—the latter would represent a sharper focusing of subjective probabilities that does not entirely eliminate uncertainty.

[8] *Time-independence*, the absence of complementarity in preference between income at time 0 and income at time 1, does not have so compelling a justification as does state-independence. For the individual will indeed be receiving a combination of consequences over time. But, in the absence of any convincing reason for anticipating positive complementarity or its reverse, the assumption of zero complementarity may be a satisfactory simplification. The assumption is widely employed in the literature of intertemporal optimization (see, e.g., Arrow (1966, p. 20)).

III. The Value of Foreknowledge: Pure Exchange

In a simplified world of pure exchange, all productive transformations among the quantities c_0, c_{1a}, and c_{1b} are ruled out—even simple storage. An individual dissatisfied with his endowment vector $Y = (y_0, y_{1a}, y_{1b})$ can modify it only by trading. Let us suppose a competitive world of "representative" individuals, characterized by identical probability beliefs and utility functions, and all holding identical endowments. Then no trading actually takes place; the price structure that emerges in market equilibrium must "sustain" the endowment pattern for every individual. Taking current corn as numeraire so that $P_0=1$, the sustaining prices must be:[9]

$$(3)\quad P_{1a} = \theta\pi_a v_{1a}'/v_0' \quad\text{and}\quad P_{1b} = \theta\pi_b v_{1b}'/v_0'$$

Wealth in c_0 units may then be determined from the definition:

$$(4)\quad W_0 = P_0 c_0 + P_{1a}c_{1a} + P_{1b}c_{1b}$$

Finally, utility attained may be calculated by appropriate substitutions in (2). This is the base situation with which the results of changes in information will be compared.

For concreteness, a numerical illustration will be employed using a logarithmic preference-scaling function v (see Table 1). Note that future state a is assumed better endowed than state b ($y_{1a}=200$, $y_{1b}=80$) as well as more probable ($\pi_a=.6$, $\pi_b=.4$). With c_0 as numeraire so that $P_0=1$, the parameters assumed lead to the solutions shown in column (4) for the sustaining prices ($P_{1a}=.3$ and $P_{1b}=.5$) and wealth ($W_0=200$). The expected utility (U

[9] The individual maximizes $U=v_0+\theta(\pi_a v_{1a}+\pi_b v_{1b})$ subject to $P_0c_0+P_{1a}c_{1a}+P_{1b}c_{1b}=P_0y_0+P_{1a}y_{1a}+P_{1b}y_{1b}$. The usual Lagrangean conditions lead to $v_0'=\lambda P_0$; $v_{1a}'=\lambda P_{1a}/\theta\pi_a$: $v_{1b}'=\lambda P_{1b}/\theta\pi_b$. With $P_0=1$, and (since all individuals have identical preferences and opportunities) $c_0=y_0$, $c_{1a}=y_{1a}$, and $c_{1b}=y_{1b}$, the results in the text are obtained.

TABLE 1—DATA AND SOLUTION FOR NUMERICAL EXAMPLE

Endowments (1)	Prior Beliefs (2)	Preference Parameters (3)	Solution, Base Case (4)
$y_0=100$	—	$\theta=1$	$P_0=1$
$y_{1a}=200$	$\pi_a=.6$	$v=log_e c$	$P_{1a}=.3$
$y_{1b}=\ 80$	$\pi_b=.4$		$P_{1b}=.5$
			$W_0=200$

$=9.5370$) is worked out in Table 2 (column (4)).

Now, suppose that a single individual at time 0 secures *private*, *prior*, and *sure* information that state a will obtain at time 1. Since one individual's choices would only negligibly affect the ruling prices, he could realize essentially all the market value $P_{1b}y_{1b}$ of his c_{1b} endowment (which he alone knows to be worthless) for reallocation to the purchase of more c_0 and/or c_{1a}. In the numerical example, this amount is $P_{1b}y_{1b}=.5(80)=40$. With the parameters assumed, it can be shown[10] that he will purchase just $40/P_{1a}=133.3$ units of c_{1a} to add to his endowed 200 units (Table 2, columns (2) and (5)). If instead he were to learn that state b will obtain, he would reallocate the entire value $P_{1a}y_{1a}=60$ of his c_{1a} endowment to purchase $60/P_{1b}=120$ units of c_{1b}. Table 2 also shows the expected utility given perfect information (and the consequent rearrangement of consumption) to be substantially higher than the expected utility under uncertainty. These expectations are calculated, of course, using the individual's prior probability estimates as to what the information will reveal.

We now come to the crucial contrast. What of the *social* value of the sure information just analyzed above? Suppose that by a collective payment to some knowledgeable outsider, an entire community consisting of the representative individuals above could all simultaneously be informed as to which future state will obtain—how large a payment would they be justified in making? The answer is: None at all! Such information would be absolutely valueless to the community as a whole. Information is of value only if it can affect action. But with identical endowments, preferences, and beliefs in a world of pure exchange, all individuals must still end up holding their endowment time-state distributions. The only thing that could happen, given the new public

[10] See Hirshleifer (1970b, pp. 9–11).

TABLE 2—PRIVATE VALUE OF INFORMATION

	Consumptive Choices[a]			Utility[b]		
	Uncertainty[c] (1)	State a[d] to obtain (2)	State b[e] to obtain (3)	Uncertainty (4)	State a to obtain (5)	State b to obtain (6)
c_0	100	100	100	4.6052	4.6052	4.6052
c_{1a}	200	333.3	—	.6 (5.2983)	5.8091	—
c_{1b}	80	—	200	.4 (4.3821)	—	5.2983
Expected Utility Under Uncertainty:				9.5370		
Conditional Utility:					10.4143	9.9035
Expected Utility Given Perfect Information:[f]					10.2100	

[a] $P_{1a}=.3$, $P_{1b}=.5$, $W_0=200$
[b] Computed according to: $U=log_e c_0+\pi_a log_e c_{1a}+\pi_b log_e c_{1b}$
[c] $\pi_a=.6$, $\pi_b=.4$
[d] $\pi_a=1$, $\pi_b=0$
[e] $\pi_a=0$, $\pi_b=1$
[f] Using prior weights $\pi_a=.6$, $\pi_b=.4$

TABLE 3—SOCIAL VALUE OF INFORMATION

	Consumptive Choices			Utility		
	Uncertainty[a] (1)	State a[b] to obtain (2)	State b[c] to obtain (3)	Uncertainty (4)	State a to obtain (5)	State b to obtain (6)
c_0	100	100	100	4.6052	4.6052	4.6052
c_{1a}	200	200	—	.6 (5.2983)	5.2983	—
c_{1b}	80	—	80	.4 (4.3821)	—	4.3821
Expected Utility Under Uncertainty:				9.5370		
Conditional Utility:					9.9035	8.9873
Expected Utility Given Perfect Information:[d]					9.5370	

[a] $\pi_a=.6$, $\pi_b=.4$; $W_0=200$; $P_{1a}=.3$, $P_{1b}=.5$
[b] $\pi_a=1$, $\pi_b=0$; $W_0=200$; $P_{1a}=.5$, $P_{1b}=0$
[c] $\pi_a=0$, $\pi_b=1$; $W_0=200$; $P_{1a}=0$, $P_{1b}=1.25$
[d] Using prior weights $\pi_a=.6$, $\pi_b=.4$.

information, is that prices shift immediately to permit "sustaining" the endowment vector in the face of the changed beliefs entering into the utility function. In the numerical example, sure public information that state a will obtain, available *prior* to the decisions at $t=0$, will cause P_{1a} to rise to .5 (while P_{1b}, of course, falls to zero). Sure public prior information that state b will obtain raises P_{1b} to 1.25, while P_{1a} falls to zero. Table 3 confirms that in these circumstances the individual will choose the same consumptions with the same probabilities as in the original uncertainty situation.

One other very important consideration must now be taken into account. There is a possibility of still greater gain for the *privately* informed individual if he is permitted to speculate rather than merely move directly to his preferred consumptive position. Assuming private knowledge that state a was to obtain, for example, an optimally speculating individual would first convert not just his c_{1b} holdings but rather *all* of his wealth $W_0=200$ to c_{1a} holdings at the old price relationships. The anticipation here is that the true information will become public, P_{1a} rising to .5 and wealth to 333.3, prior to the finalizing of the consumption-investment decisions at $t=0$. Note that the individual with private information would have every incentive to publicize that information, *after* making his speculative commitment. The enormously enhanced private results achievable via speculation are detailed in Table 4.

So far, two reaction modes of the privately informed individual have been considered: consumptive adaptation, and optimal speculation. A third and even more attractive possibility is *resale of the information* itself. The potential gain then becomes enormous, since the individual is no longer constrained by his personal commodity endowment. However, it may not be easy for an informed individual to authenticate possession of valuable foreknowledge for resale purposes. After all, anyone could *claim* to have such knowledge. Feasible and optimal resale strategies, and the market value of resold information, are issues that cannot be pursued here. The crucial point remains that *the community as a whole obtains no benefit, under pure exchange, from either the acquisition or the dissemination (by resale or otherwise) of private foreknowledge.*

The contrast between the private profitability and the social uselessness of foreknowledge may seem surprising. In-

TABLE 4—PRIVATE VALUE OF INFORMATION, WITH SPECULATION

	Consumptive Choices			Utility		
	Uncertainty[a]	State a[b] to obtain	State b[c] to obtain	Uncertainty	State a to obtain	State b to obtain
c_0	100	166.7	250	4.6052	5.1160	5.5215
c_{1a}	200	333.3	—	.6 (5.2983)	5.8091	—
c_{1b}	80	—	200	.4 (4.3821)	—	5.2983
Expected Utility Under Uncertainty:				9.5370		
Conditional Utility:					10.9251	10.8198
Expected Utility Given Perfect Information:[d]					10.8830	

[a] $\pi_a=.6$, $\pi_b=.4$; $W_0=200$; $P_{1a}=.3$, $P_{1b}=.5$
[b] $\pi_a=1$, $\pi_b=0$; $W_0=333.3$; $P_{1a}=.5$, $P_{1b}=0$
[c] $\pi_a=0$, $\pi_b=1$; $W_0=500$; $P_{1a}=0$, $P_{1b}=1.25$
[d] Using prior weights $\pi_a=.6$, $\pi_b=.4$.

formation is widely considered to be a classic example of a "collective good," the type of commodity for which private incentives are supposed to lead to under-provision rather than over-provision on the market. Indeed, there may be something of a collective-good aspect to the *market* information alluded to earlier: information that helps improve an otherwise imperfect process of exchange. But the expenditure of real resources for the production of *technological* information is socially wasteful in pure exchange, as the expenditure of resources for an increase in the quantity of money by mining gold is wasteful, and for essentially the same reason. Just as a smaller quantity of money serves monetary functions as well as a larger, the price level adjusting correspondingly, so a larger amount of foreknowledge serves no social purpose under pure exchange that the smaller amount did not.

IV. The Value of Foreknowledge: Production and Exchange

Consider now the more realistic regime in which production and exchange both take place. Assume that endowments are just the same as before, for all individuals. But suppose that, in addition, each representative individual has a small discrete productive investment opportunity of the following form: exactly 1 unit of endowed c_0 may be sacrificed to produce additional income in either time-state $1a$ or time-state $1b$ (but not both). Suppose that the choice is between a yield of $2\frac{1}{2}$ units in state a or $2\frac{1}{2}$ units in state b. With the prices of the initial situation in the example above ($P_{1a}=.3$, $P_{1b}=.5$), every representative individual would choose the latter alternative; he would physically invest, transforming his endowment combination ($y_0=100$, $y_{1a}=200$, $y_{1b}=80$) into the attained combination ($c_0=99$, $c_0=200$, $c_{1b}=82.5$). Since the scale of the collective investment is not infinitesimal, the prices change slightly but not by enough to modify the desirability of the selection made.

Suppose now that *one single* individual is given sure, prior, and private information that state a will obtain. Here it would be socially desirable that this individual's investment sacrifice of c_0 (and everyone else's, as well) be redirected so as to produce c_{1a} instead of the useless c_{1b}. But if the information is private, the original prices must still be ruling so that the individual's incentives for production decisions remain unchanged. He will continue to invest for a c_{1b} return, despite knowing that the latter will turn out to be valueless. It is more profitable for him to commit the resources to c_{1b}, merely taking care to arrange in advance for the liquidation of the $2\frac{1}{2}$ units of c_{1b} (in addition, of course, to his endowed 80 units) at the currently ruling market prices. *Thus, as under the regime of pure exchange, private foreknowledge makes possible large private profit without leading to socially useful activity.* The individual would have just as much incentive as under pure exchange (even more, in fact) to expend real resources in generating socially useless private information.

What of the value of *public* information? If the information were made public that state a would obtain, P_{1a} would jump to .5 (P_{1b} falling to zero). Then the individual investments would all be shifted so as to yield c_{1a} instead of c_{1b}. This, of course, is socially efficient behavior. *Public information as to which state will obtain is indeed of social value in a regime of production and exchange.* However, it remains true that the value of private foreknowledge is enormously greater to any individual than the value to him of public foreknowledge. In the example used here, public information enables the representative individual to attain the consumption sequence ($c_0 = 99$, $c_1 = 202.5$) with probability .6, or the sequence ($c_0 = 99$, $c_1 = 82.5$) with probability .4. Private information enables him to attain with probability .6 the sequence ($c_0 = 99$, $c_1 = 337.5$)—based on converting his 82.5 units of c_{1b} at the original price ratio into 137.5 units of c_{1a} to be added to his endowed 200 units—or with probability .4 the sequence ($c_0 = 99$, $c_1 = 202.5$). Evidently, the possibilities with private information are far superior (still leaving aside the prospect of much greater gains through speculation and/or resale). Thus, the incentives for the use of resources to generate private information remain excessive.

What about speculation and resale? Having undertaken a speculative commitment, it is in the interest of the informed individual to publicize the information. Whether or not involved in speculation, the informed individual would find it advantageous wherever possible to resell the information. Under pure exchange, where foreknowledge is socially valueless, devotion of resources to dissemination is only a further social waste. In a regime of production, however, universal dissemination would improve the choice of investments. The partial dissemination that would ensue from private publicizing or through resale would also tend to shift prices and lead to some productive adaptation. Thus, *in a regime of production, the dissemination of information has social utility,* against which gain must be offset, of course, any resource cost of the dissemination process.

V. Distributive Considerations, Public Information, and Homogeneity of Beliefs

The key factor underlying all the results obtained above is the distributive significance of private foreknowledge. When private information fails to lead to improved productive alignments (as must necessarily be the case in a world of pure exchange, and also in a regime of production unless there is dissemination effected in the interests of speculation or resale), it is evident that the individual's source of gain can only be at the expense of his fellows. But even where information is disseminated and does lead to improved productive commitments, the distributive transfer gain will surely be far greater than the relatively minor productive gain the individual might reap from the redirection of his own real investment commitments.

Will *public* information have distributive implications, and if so, will this consideration provide additional private motivation for the generation of public information? The nature and direction of possible distribution effects turn upon the timing of information acquisition in comparison with the schedule of trading. Two alternative timing patterns will be considered here: 1) The information is publicly released before the opening of trading, or 2) the individuals trade to their consumptive optimum positions prior to the release of the information, with another round of trading permitted afterward.[11] Both trading and generation of information are best regarded as essentially continuous interacting processes, so that the second timing pattern seems more acceptable.[12] But the first is useful in emphasizing certain aspects of reactions to public information.

We will therefore imagine, first, a situation of pure exchange in which the true state of the world is announced in advance of any market trading whatsoever—while individuals are still at their endowment positions. Announcement that state a will obtain (or, more generally, release of any information tending to increase the probability π_a that individuals attach to state a) will, of course, enhance the position of those disproportionately endowed with state a claims. The rise in the price P_{1a} will enrich such individuals. It will also enhance the position of those whose tastes or beliefs previously inclined them in the direction of purchase of state b claims. For, such individuals would otherwise have largely wasted their income endowments in the purchase of worthless state b claims.

That public information has distributive implications does not, however, lead necessarily to the conclusion that private individuals will want to generate public information. Individuals disproportionately endowed with state a claims, for example, cannot be sure in advance that the information will not point to state b rather than state a. And indeed, it can be shown that in the circumstances assumed here, risk-averse individuals will prefer that the information not be released.[13] For, the anticipation of public information becoming available in advance of trading adds a significant *distributive risk* to the underlying *technological risk* (as to which state will obtain). A community of such individuals would actually pay something to a knowledgeable outsider not to reveal, in advance of market trading, which state will obtain! (This conclusion would have to be modified somewhat under a regime of production and exchange; the gain from redirection of productive investments achieved in consequence of the public information would have to be offset against the increased distributive risk.)

Let us turn now to the more reasonable assumption that individuals have already optimally adapted their decisions to their opportunities prior to the release of new public information. Differences of endowments would no longer have any relevance, and so there would be no net incentive for or against the acquisition of socially neutral information under pure exchange. (And there would be an appropriately small incentive for any one individual to support the acquisition of beneficial public information in a world of production.) A similar argument can be made about differences in tastes or beliefs so long as the individuals may be presumed to have

[11] If no trading were permitted once the information was revealed, individuals' consumptive baskets (here, holdings of c_0 and c_1) would in general be non-Pareto optimal. That is, differences across individuals in marginal rates of substitution between commodities would persist. Such a model has been studied by Ross Starr. The non-Pareto optimality stemming from informational differences has also been noted by Earl A. Thompson (fn. 5) and by Arrow (1969, pp. 54–56).

[12] The second timing pattern corresponds to the dictum that, at any moment of time, the market has already "discounted" (allowed for) all publicly available information.

[13] See Hirshleifer (1970b, pp. 20–22).

merely moved to their consumptive optimum positions, and not engaged in speculative behavior. But, we know that for individuals with superior information there is a strong incentive to take speculative positions. Now, differences of beliefs amount to the same thing as *each individual's thinking that he is in possession of superior information.* Such differences open up a new range of possibilities.

We saw above that it was privately rational, for a better informed individual, to expend resources for the dissemination of socially neutral information—after having adopted a speculative commitment. With inhomogeneity of beliefs every person may be better informed, in his own opinion! Thus, the generation of public information is (from his point of view) nothing other than the dissemination of information already privately available to him. He will expect to reap speculative profits from this process. But so will other individuals, with quite opposed opinions! We therefore have rather strong grounds to anticipate that in these circumstances excessive resources will be devoted to the generation of public information.

These considerations may be clarified by reference to a well-known activity for the generation of public information—horse racing. Viewed as a research activity, horse racing may be presumed to have a small positive social value: the identification of faster horses works "to improve the breed." This consideration is evidently a very minor motivating factor for the activity in comparison with the opportunity to speculate upon one's supposedly superior knowledge. Without differences of opinion, it is said, there would be no horse races. That is, the social value is insufficient to motivate the research—the activity is founded upon the contradictory expectations of speculative gain.

Suppose that it costs $100 in real resources to run a horse race, and that the social advantage of knowing which is the fastest horse is just $5. Evidently, if the race is run society is engaging in excessive research. Now imagine that the potential speculative gain, to an individual convinced that his horse is truly faster, is just $90—he could still not earn enough, himself, to cover the costs of the race. But if several individuals are so convinced, each about his own horse, they may cooperate to stage the experiment. So conflict of beliefs may enormously compound the speculative factor that, even from the point of view of a single individual, tends to promote excessive investment in information-generating activity.

VI. The Value of Discovery Information

The acquisition of technological information usually refers to the detection of properties of Nature that permit the development of new tools or the utilization of new techniques. This is the type of information categorized as discovery above, in which Nature's secret will not be autonomously revealed but must be extracted by man. The necessity for human interposition makes the analysis of the value of discovery information somewhat more complex than the analysis of foreknowledge information.

For concreteness, consider the following situation. Suppose that if an alloy with an enormously high melting point of $X°$ can be created, extremely cheap thermonuclear power will become feasible. The underlying state of the world is not the result of a probabilistic process: such an alloy may in fact be possible to create (state a) or may not (state b). While this is not a stochastic situation, it has been shown to be useful even in such circumstances to summarize our uncertainty in the form of a probability distribution.[14] Thus, just as in the case of foreknowledge,

[14] See Leonard J. Savage.

we can assume that individuals assign probabilities π_a and π_b to the two underlying states of the world. However, even if the favorable state a is the true one, Nature is not going to tell us herself. In the discovery situation, no news is bad news.

From the point of view of any individual, however, the picture may not look very different from that analyzed under the heading of foreknowledge. For any individual there is a certain probability π_A of "good news" (discovery of the alloy), due to the actions of other men if not of his own. We can think of a compound event A which consists of the joint happenings "State a is true (the required alloy is possible) *and* this fact is successfully exploited (the alloy is created) within the time-period envisaged." Evidently, $\pi_A \leq \pi_a$, the probability of good news is generally less than the probability attached to the more favorable state of Nature. And similarly, if the event B is defined in a complementary way as representing "no news" (identical with "bad news" in the circumstances considered), we have $\pi_B \geq \pi_b$. The individual's decisions—for example, whether to invest in a productive process whose profitability will be highly sensitive to the prospect of cheap thermonuclear power—will run in terms of the probabilities of good and bad news rather than the probabilities attached to the states of nature.

With this modification, the analysis is essentially similar to what has gone before. We need only consider the more general regime of production and exchange. Given private, prior, and sure information of event A, the individual in a world of perfect markets would *not* adapt his productive decisions if he were sure the information would remain private until after the close of trading. For, prices of the time-state claims c_{1A} and c_{1B} (involving the observable states A and B, of course, not the "natural" states a and b which do not directly affect markets) will not have changed. However, as before it would be in his interest to speculate and/or resell the information, in which case prices will tend to shift. The obvious way of acquiring the private information in question is, of course, by performing technological research.[15] By a now familiar argument we can show once again that the distributive advantage of private information provides an incentive for information-generating activity that may quite possibly be in excess of the social value of the information.

The conclusions reached in the analysis of foreknowledge with respect to public information again carry over to the discovery situation. Public information is socially valuable in redirecting productive decisions, and to that extent individuals will rationally combine (through government and other instruments) to generate public information (or, in some cases, it will pay even a single individual to do so). But disparities of beliefs (differences in probability estimates) may lead to agreement upon a procedure of generating public information where social costs exceed the social benefit.

VII. Implications for Patent Policy

Eli Whitney obtained one of the first American patents, in 1794, for his cotton gin. With some business associates, he spent many years and invested considerable resources in the attempt to protect his patent and prosecute infringements. These efforts were largely fruitless. It is reasonable to infer that potential inventors, both before and after Whitney, have been deterred from searching for new knowedge by the fear of a similar outcome—hence the argument for effective patent protection. On the other hand, had

15 This is not the only way. The information might be purchased (or stolen) from some other person.

Whitney succeeded in obtaining the terms he demanded from users of his idea, the enormous expansion that actually took place in the production and consumption of cotton would have been significantly hampered.[16] This conflict between the "static" disadvantage of a patent monopoly and the "dynamic" advantage of encouraging invention is quite properly emphasized in the traditional literature.[17]

But what seems to have been overlooked is that there were other routes to profit for Whitney. The cotton gin had obvious speculative implications for the price of cotton, the value of slaves and of cotton-bearing land, the business prospects of firms engaged in cotton ware-housing and shipping, the site values of key points in the transport network that sprang up. There were also predictable implications for competitor industries (wool) and complementary ones (textiles, machinery). It seems very likely that some forethoughted individuals reaped speculative gains on these developments, though apparently Whitney did not. And yet, he was the first in the know, the possessor of an unparalleled opportunity for speculative profit. Alternatively, of course, Whitney could have attempted to keep his process secret except to those who bought the information from him.

The issues involved may be clarified by distinguishing the "technological" and "pecuniary" effects of invention. The technological effects are the improvements in production functions—interpreted in the widest sense to include the possible production of new commodities, the discovery of new resources, etc.—consequent upon the new idea. The pecuniary effects are the wealth shifts due to the price revaluations that take place upon release and/or utilization of the information. The pecuniary effects are purely redistributive.[18]

For concreteness, we can think in terms of a simple cost-reducing innovation. The technological benefit to society is, roughly, the integrated area between the old and new marginal-cost curves for the preinvention level of output plus, for any additional output, the area between the demand curve and the new marginal-cost curve. The holder of a (perpetual) patent could ideally extract, via a perfectly discriminatory fee policy, this entire technological benefit. Equivalence between the social and private benefits of innovation would thus induce the optimal amount of private inventive activity. Presumably, it is reasoning of this sort that underlies the economic case for patent protection. It is true that under a patent system there will, in general, be some shortfall in the return to the inventor, due to costs and risks in acquiring and enforcing his rights, their limited duration in time, and the infeasibility of a perfectly discriminatory fee policy. On the other side are the recognized disadvantages of patents: the social costs of the administrative-judicial process, the possible anti-competitive impact, and restriction of output due to the marginal burden of patent fees.[19] As a second best kind of judgment, some degree of patent protection has seemed a reasonable compromise among the objectives sought.

But recognition of the unique position of the innovator for forecasting and consequently capturing portions of the *pecuniary* effects—the wealth transfers due to price revaluations—may put matters in a

[16] Whitney and his partners planned to retain all the ginning in their own hands, buying the raw product and selling the ginned cotton (Dumas Malone, vol. 10, p. 159).

[17] See Machlup.

[18] For a discussion in the context of government resource-investment policy, see Roland McKean (ch. 8).

[19] A perfectly discriminatory fee system would place no marginal burden and thus would not lead to any restriction of output.

different light. The "ideal" case of the perfectly discriminating patent holder earning the entire technological benefit is no longer so ideal. For, the same inventor is in a position to reap speculative profits, too; counting these as well, he would clearly be overcompensated.

Consider now the opposite extreme. Do we have reason to believe that the potential speculative profits to the inventor, from the pecuniary effects that will follow release of the information at his unique disposal, will be so great that society need take no care to reserve for him any portion of the technological benefit of his innovation? The answer here is indeterminate. There is no logically necessary tie between the size of the technological benefit on the one hand, and the amplitude of the price shifts that create speculative opportunities on the other.[20]

Even if the prospective price revaluations are ample, however, there will be limitations to the inventor's capacity to profit from them. For, speculative profits are constrained by the magnitude of feasible speculative commitments. If the possessor of prior information acts alone, he is limited by what may be a puny wealth endowment. But if he tries to sell his information, in effect buying a share in a larger speculative pool, he will find it difficult to consummate such a transaction. The most important limitation of all has not heretofore been taken up in this paper, but must be considered in a policy discussion: imperfection of markets for time-state claims.[21] Given the inconceivably vast number of potential contingencies and the costs of establishing markets, the prospective speculator will find it costly or even impossible to purchase neutrality from "irrelevant" risks. Eli Whitney could not be *sure* that his gin would make cotton prices fall: while a considerable force would clearly be acting in that direction, a multitude of other contingencies might also have possibly affected the price of cotton. Such "uninsurable" risks gravely limit the speculation feasible with any degree of prudence.

We are left, therefore, in an agnostic position. The fundamental argument for patent protection is gravely weakened when it is recognized that the pecuniary effects of the invention are a potentially enormous source of return to the inventor, quite apart from the technological benefit that the patent system attempts to reserve for him. But we cannot show that no patent protection at all is warranted, that the profits from speculation or from resale[22] suffice for an appropriate inducement to invention. These profits may more than suffice, or they may fall substantially short; there is no necessary relation at all between the magnitudes of the technological and the pecuniary effects. Or, more precisely, between the magnitudes of that fraction of the technological effect that a patentee can capture and that fraction of the pecuniary effect that a speculator on prior information can capture.

VIII. Summary

In the model of this paper, markets are assumed to be perfect. Uncertainty attaches only to individuals' perceptions of their endowments and productive opportunities (technological uncertainty). The private and social values of two main

[20] A relatively minor shift in locomotive technology, for example, might lead railroad planners to select an entirely different route for a new line, with drastic upward and downward shifts of land values. Paul Samuelson emphasizes, p. 974, the disproportionality between the gain reaped by the first-in-time speculator and the social utility of his activity.

[21] This imperfection has been emphasized by Arrow (1962, and also 1969).

[22] Resale of information does not stand on quite the same footing as speculation. Speculation is an extra source of gain, whether or not patent has been obtained, whereas resale of information otherwise kept secret is an *alternative* to obtaining a patent.

categories of technological information were considered: 1) foreknowledge of states of the world that will in time be revealed by Nature herself (e.g., the weather), and 2) discovery of hidden properties of Nature that can only be laid bare by human action.

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. There is an incentive for individuals to expend resources in a socially wasteful way in the generation of such information. Public information, in contrast, does affect productive decisions in a socially appropriate way. Speculative profits from the price revaluations to be anticipated provide the knowledgeable individual with an incentive to disseminate (publicize) his private information. Still greater profit is possible if the information can be resold. In a world of pure exchange, there will in general be private overinvestment in information: resources committed to acquisition and to dissemination are both wasted from the social point of view. In a world of production, however, the gains from productive rearrangements due to the information must be offset against the costs of acquisition and dissemination; there may or may not be private overinvestment.

Distributive considerations enter also into the motivation for the acquisition of *public* information. To the extent that the prospect of such information imposes a distributive risk upon individuals—due, for example, to possible revaluation of endowment holdings—there will be an aversion to socially neutral and even (to some degree) to socially beneficial public information. Probably more important is a force acting in the opposed direction. With inhomogeneous beliefs, individuals with differing opinions will tend each to believe that revelation of new information will favor his own speculative commitments. Hence, a group of such individuals might willingly cooperate in making expenditures far in excess of the social value of the information to be acquired.

The standard literature on the economics of research and invention argues that there tends to be private underinvestment in inventive activity, due mainly to the imperfect appropriability of knowledge. The contention made is that, even with a patent system, the inventor can only hope to capture some fraction of the technological benefits due to his discovery. This literature overlooks the consideration that there will be, aside from the technological benefits, pecuniary effects (wealth redistributions due to price revaluations) from the release of the new information. The innovator, first in the field with the information, is able through speculation or resale of the information to capture a portion of these pecuniary effects. This fact is socially useful in motivating release of the information. Even though practical considerations limit the effective scale and consequent impact of speculation and/or resale, the gains thus achievable eliminate any a priori anticipation of underinvestment in the generation of new technological knowledge.

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