INFORMATION AND EFFICIENCY: ANOTHER VIEWPOINT*

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THE importance of bringing economic analysis to bear on the problems of efficient economic organization hardly requires comment, but there is a need to review the manner in which the notion of efficiency is used in these problems. The concept of efficiency has been abused frequently because of the particular approach used by many analysts. My aim is to examine the mistakes and the vagueness associated with this approach. I shall focus attention on the problem of efficiently allocating resources to the production of information because in this case the issues stand out clearly. Since Kenneth J. Arrow's paper "Economic Welfare and the Allocation of Resources for Invention"[1] has been most influential in establishing the dominant viewpoint about this subject, my commentary necessarily is a critique of Arrow's analysis.

The view that now pervades much public policy economics implicitly presents the relevant choice as between an ideal norm and an existing "imperfect" institutional arrangement. This *nirvana* approach differs considerably from a *comparative institution* approach in which the relevant choice is between alternative real institutional arrangements. In practice, those who adopt the nirvana viewpoint seek to discover discrepancies between the ideal and the real and if discrepancies are found, they deduce that the real is inefficient. Users of the comparative institution approach attempt to assess which alternative real institutional arrangement seems best able to cope with the economic problem; practitioners of this approach may use an ideal norm to provide standards from which divergences are assessed for all practical alternatives of interest and select as efficient that alternative which seems most likely to minimize the divergence.[2]

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[1] Kenneth J. Arrow, Economic Welfare and the Allocation of Resources for Invention, in The Rate and Direction of Inventive Activity, 609-25 (1962).

[2] A practitioner of the nirvana approach sometimes discusses and compares alternative institutional arrangements. But if all are found wanting in comparison with the ideal, all are judged to be inefficient.

The nirvana approach is much more susceptible than is the comparative institution approach to committing three logical fallacies—*the grass is always greener fallacy, the fallacy of the free lunch,* and *the people could be different fallacy.* The first two fallacies are illustrated in a general context in part I of what follows; in part II, they and the third fallacy arise in contexts more specific to the economics of knowledge. Part III is a discussion of Arrow's conclusion about the role of monopoly in the production of knowledge, and part IV offers a general criticism of the nirvana approach.

I

The grass is always greener fallacy can be illustrated by the following two quotations from Arrow's paper.

> To sum up, we expect a free enterprise economy to underinvest in invention and research (as compared with an ideal) because it is risky, because the product can be appropriated only to a limited extent, and because of increasing returns in use. This underinvestment will be greater for more basic research. Further, to the extent that a firm succeeds in engrossing the economic value of its inventive activity, there will be an under-utilization of that information as compared with an ideal allocation.[3]
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> . . . .
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> The previous discussion leads to the conclusion that for optimal allocation to invention it would be necessary for the government or some other agency not governed by profit-and-loss criteria to finance research and invention.[4]

An examination of the correctness of the premise is the main task of this paper, but for present purposes the premise contained in the first quotation can be assumed to be correct. It is clear from both quotations and from the text in which these quotations are imbedded that Arrow is claiming that free enterprise does not result in an ideal allocation of resources to the production of knowledge. From this premise he draws the general conclusion, given in the second quotation, that optimal allocation requires that the government or other nonprofit agency should finance research and invention.

Whether the free enterprise solution can be improved upon by the substitution of the government or other nonprofit institutions in the financing of research cannot be ascertained solely by examining the free enterprise solution. The political or nonprofit forces that are substituted for free enterprise must be analyzed and the outcome of the workings of these forces must be compared to the market solution before any such conclusions can be drawn.

[3] Kenneth J. Arrow, *supra* note 1, at 619.

[4] *Id.* at 623.

Otherwise, words such as "government" and "nonprofit" are without analytical content and their use results in confusion. Since Arrow does not analyze the workings of the empirical counterparts of such words as "government"[5] and "nonprofit," his conclusion can be clarified by restating it as follows: "The previous discussion leads to the conclusion that for optimal allocation to invention it would be necessary to remove the nonoptimalities." The same charge, of course, can be levied against those who derive in a similar way the opposite policy conclusion, one that calls for a reduction in the role played by government.[6]

Given the nirvana view of the problem, a deduced discrepancy between the ideal and the real is sufficient to call forth perfection by incantation, that is, by committing the grass is always greener fallacy. This usually is accomplished by invoking an unexamined alternative. Closely associated in practice with this fallacy is the fallacy of the free lunch. An example of the latter is given in Arrow's discussion of the difficulties posed for the competitive system by uncertainty.

> I will first sketch an ideal economy in which the allocation problem can be solved by competition and then indicate some of the devices in the real world which approximate this solution.
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> Suppose for simplicity that uncertainty occurs only in production relations. Producers have to make a decision on inputs at the present moment, but the outputs are not completely predictable from the inputs. . . . [T]he outputs [are] determined by the inputs and a 'state of nature.' Let us define a 'commodity-option' as a commodity in the ordinary sense labeled with a state of nature. . . .
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> Suppose—and this is the critical idealization of the economy—we have a market for all commodity-options. What is traded on each market are contracts in which buyers pay an agreed sum and the sellers agree to deliver prescribed quantities of a given commodity *if* a certain state of nature prevails and nothing if that state of nature does not occur. For any given set of inputs, the firm knows its output under each state of nature and sells a corresponding quantity of commodity options; its revenue is then completely determined. It may choose its inputs so as to maximize profits. . . .

[5] This is a slight exaggeration. Arrow, in the last few paragraphs of his paper does discuss some problems in substituting the government for the market. The important point, however, is that Arrow is not led to reconsider his allegation of inefficiency in the market place by his short discussion of some of the difficulties of resorting to government.

[6] But for economists at least, the charge of committing the grass is always greener fallacy must be less severe in this case. The economist who suggests that we resort to the market because of unsatisfactory experience with government at least can claim professional knowledge of how the market can be expected to allocate resources. See pt. IV, pp. 19-20 *infra*.

An equilibrium is reached on all commodity-option markets, and this equilibrium has precisely the same Pareto-optimality properties as competitive equilibrium under uncertainty.

In particular, the markets for commodity-options in this ideal model serve the function of achieving an optimal allocation of risk-bearing among the members of the economy. . . .

But the real economic system does not possess markets for commodity-options.[7]

Here I must raise an objection, for there is nothing in principle that prohibits the sale of commodity options. The real economic system does, in fact, allow exchange of commodity-options.[8] Arrow continues:

[If commodity options are unavailable] the firm and its owners cannot relieve themselves of risk-bearing in this model. Hence any unwillingness or inability to bear risks will give rise to a nonoptimal allocation of resources, in that there will be discrimination against risky enterprises as compared with the optimum.[9]

Arrow here has slipped into the fallacy of the free lunch. The word "nonoptimal" is misleading and ambiguous. Does it mean that free enterprise can be improved upon? Let me suppose that the cost of marketing commodity options exceeds the gain from the adjustment to risk. This would account for their presumed absence. Can it then be said that free enterprise results in a nonoptimal adjustment to risk? To make this assertion is to deny that scarcity is relevant to optimality, a strange position for an economist. In suggesting that free enterprise generates incomplete adjustments to risk, the nirvana approach, by comparing these adjustments with the ideal, is led further to equate incomplete to nonoptimal. This would be correct only if commodity-options or other ways of adjusting to risk are free. In this way, the nirvana approach relies on an implicit assumption of nonscarcity, but since risk shifting or risk reduction cannot generally be accomplished freely the demonstration of nonoptimality is false.

[7] Kenneth J. Arrow, *supra* note 1, at 610-11.

[8] A labor contract with an adjustment for changes in the Consumer Price Index is a commodity-option. Such a contract specifies one wage rate if nature reveals one price level and another wage rate conditional upon the appearance of a different price level. Insurance premiums often contain deduction provisions if nature helps the driver avoid an accident. Firms often will sell products to other firms with the price conditional on delivery date, product quality, and prices that are being paid by other firms at the time of delivery. The American housewife is persistently offered a money back guarantee conditional on quality and sometimes independent of quality. Numerous other examples of commodity-options can be cited, such as limit orders to buy or sell that specify reservation prices, but there is no need here for a survey of the great variety of contractual relationships that exist.

[9] Kenneth J. Arrow, *supra* note 1, at 611-12.

II

Arrow calls attention to three problem areas in the production of knowledge and invention, risk-aversion, indivisibilities, and inappropriability. These are discussed in this section. In his analysis of risk-aversion, Arrow recognizes three major substitutes for commodity-option contracts: insurance, common stock, and cost-plus contracts. He finds that each of these fails to completely eliminate the discrepancy between optimal allocation in his ideal norm and allocation in a free enterprise system:

> (1) the economic system has devices for shifting risks, but they are limited and imperfect; hence, one would expect an underinvestment in risky activities; (2) it is undoubtedly worthwhile to enlarge the variety of such devices, but the moral factor creates a limit to their potential.[10]

The route by which he reaches these conclusions is revealed by his discussion of the adjustment to risk provided by insurance.

> Suppose that each firm and individual in the economy could forecast perfectly what prices would be under each state of nature. Suppose further there were a lottery on the state of nature, so that before the state of nature is known any individual or firm may place bets. Then it can be seen that the effect . . . is the same as if there were markets for commodity-options of all types. . . .
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> References to lotteries and bets may smack of frivolity, but we need only think of insurance to appreciate that the shifting of risks through what are in effect bets on the state of nature is a highly significant phenomenon. If insurance were available against any conceivable event, it follows . . . that optimal allocation would be achieved. . . .
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> Unfortunately, it is only too clear that the shifting of risks in the real world is incomplete. There are a number of reasons why this should be so, but I will confine myself to one, of special significance with regard to invention. In insurance practice, reference is made to the moral factor as a limit to the possibilities of insurance. . . . The insurance policy changes the incentive of the insured [in the case of fire insurance], creating an incentive for arson or at the very least for carelessness. . . . As a result, any insurance policy and in general any device for shifting risks can have the effect of dulling incentives. . . .
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> The moral factor [is] of special relevance in regard to highly risky business activities, including invention. . . . [S]uch activities should be undertaken if the expected return exceeds the market rate of return, no matter what the variance is. The existence of common stocks would seem to solve the allocation problem; any individual stockholder can reduce his risk by buying only a small part of the stock and diversifying his portfolio to achieve his own preferred risk level. But then again the actual managers no longer receive the full reward of their decisions; the

[10] *Id.* at 614.

shifting of risks is again accompanied by a weakening of incentives to efficiency. Substitute motivations whether pecuniary . . . or nonpecuniary . . . may be found, but the dilemma of the moral factor can never be completely resolved.[11]

My dissatisfaction with Arrow's approach can be explained by first referring to one sentence in the above quotation. "[S]uch activities should be undertaken if the expected return exceeds the market rate of return, no matter what the variance is."[12] This statement would certainly be false for a Robinson Crusoe economy. Suppose that the expected rate of return on one project equals the expected rate of return on a second project. If the variances of the expected returns differ, and if Crusoe is risk averse, there is good economic reason for Crusoe to prefer the less risky project. Reduction of risk is by hypothesis an economic good for Crusoe and he should be willing to pay a positive price, such as a lower expected return, in order to acquire this good. It is clear in this simple case that the economist has no more reason for saying that Crusoe should be indifferent between these projects than he has for saying that Crusoe should be risk neutral.

Once it is admitted that risk reduction is stipulated to be an economic good, the relevant question for society is what real institutional arrangements will be best suited to produce risk reduction or risk shifting. We no longer delude ourselves into thinking that the world would be a more efficient place if only people were not risk averse; the taste for risk reduction must be incorporated into the concept of efficiency.

Given the fact of scarcity, risk reduction is not achievable at zero cost, so that the risk averse efficient economy, as we have already noted, does *not* produce "complete" shifting of risk but, instead, it reduces or shifts risk only when the economic gain exceeds the cost. Once we seek to compare different institutional arrangements for accomplishing this, it is difficult to keep scarcity from entering our calculations so that it becomes obviously misleading and incorrect to assert that an economy, free enterprise or otherwise, is inefficient if it fails to economize on risk as it would if it were costless to shift or reduce risk.

Two types of adjustment to risk seem possible: pooling independent activities so that the variance in expected return is reduced and facilitating the assumption of risk by those who are less risk averse. The market is an institutional arrangement that encourages both types of adjustment by rewarding

[11] *Id.* at 612-14.

[12] In the original text, Arrow places a footnote here—"The validity of this statement depends on some unstated assumptions, but the point to be made is unaffected by minor qualifications." The reader perhaps may be able to guess what is meant here and how it would affect my criticism.

those who successfully reduce or shift risk. Thus, future contracts provide a method whereby much risk is shifted to speculators.[13] Conditional contracts of the commodity-option type already discussed also can be purchased for a premium. And even with risk pooling, some risk remains to be borne by sellers of insurance, so that a payment for risk bearing is in order.

Moral hazard is identified by Arrow as a unique and irremedial cause of incomplete coverage of all risky activities by insurance. But in truth there is nothing at all unique about moral hazard and economizing on moral hazard provides no special problems not encountered elsewhere. Moral hazard is a relevant cost of producing insurance; it is not different from the cost that arises from the tendency of men to shirk when their employer is not watching them. And, just as man's preference for shirking and leisure are costs of production that must be economized, so moral hazard must be economized in shifting and reducing risk. A price can be and is attached to the sale of all insurance that includes the moral hazard cost imposed by the insured on insurance companies. And this price is individualized to the extent that other costs, mainly cost of contracting, allow. The moral hazard cost is present, although in differing amounts, no matter what percentage of the value of the good is insured.

The moral hazard problem is no different than the problem posed by any cost. Some iron ore is left unearthed because it is too costly to bring to the surface. But we do not claim ore mining is inefficient merely because mining is not "complete." Some risks are left uninsured because the cost of moral hazard is too great and this may mean that self-insurance is economic. There is no special dilemma associated with moral hazard, but Arrow's concentration on the divergence between risk shifting through insurance and risk shifting in the ideal norm, in which moral hazard presumably is absent, makes it appear as a special dilemma. While it may cost nothing to insure risky enterprises in the world of the ideal norm, it does in this world, if for no other reason than the proclivity of some to commit moral hazards. Arrow's approach to efficiency problems has led him directly to "the people could be different" fallacy.

Payment through insurance premiums for the moral hazard cost imposed on insurance sellers brings into play the usual price mechanism for economizing. The fact that not everything is insured is irrelevant to the question of efficiency. The absence of insurance, especially when moral hazard is important, merely is evidence of the unwillingness to shift all risk to others at

[13] It is not yet clear from available empirical studies whether speculators are in fact compensated, and it has been argued either that they are not risk-averse or that they enjoy the sport so much that they are willing to bear risk without pay.

premium levels that cover the cost imposed on sellers of insurance by these moral hazards.[14]

Clearly, efficiency requires that moral hazards be economized. Otherwise, we implicitly assert that the loss of assets that accompanies the realization of a moral hazard imposes no cost on society. One way of economizing on moral hazards is to allow self-insurance. If the size of the premium that is required to get others to accept moral hazard cost is higher than people wish to pay, it is appropriate to reduce the loss of assets that would accompany moral hazard by allowing prospective buyers of such insurance to self-insure.

Do we shift risk or reduce moral hazards efficiently through the market place? This question cannot be answered solely by observing that insurance is incomplete in coverage. Is there an alternative institutional arrangement that seems to offer superior economizing? There may well be such an arrangement, but Arrow has not demonstrated it and, therefore, his allegation of inefficiency may well be wrong and certainly is premature.

Turning now to the possibility of reducing risk through the device of pooling, we find that Arrow takes the following position.

> The central economic fact about the processes of invention and research is that they are devoted to the production of information. By the very definition of information, invention must be a risky process. . . . Since it is a risky process, there is bound to be some discrimination against investment in inventive and research activities. . . . The only way, within the private enterprise system, to minimize this [moral factor] problem is the conduct of research by large corporations with many projects going on, each small in scale compared with the net revenue of the corporation. Then the corporation acts as its own insurance company. But clearly this is only an imperfect solution.[15]

[14] Arrow employs the moral hazard argument in his paper, Uncertainty and the Welfare Economics of Medical Care, 53 Am. Econ. Rev. 941-73 (1963). Mark V. Pauly criticized this use of the moral hazard argument and Arrow replied to the criticism 58 Am. Econ. Rev. 531-38 (1968). My criticism of Arrow's argument is much the same as Pauly's. Two parts of Arrow's reply to Pauly should be noted. First, Arrow concedes "that the optimality of complete insurance is no longer valid when the method of insurance influences the demand for the services provided by the insurance policy." So far so good. However, secondly, Arrow states that "If the amount of insurance payment is in any way dependent on a decision of the insured as well as on a state of nature, then optimality will not be achieved either by the competitive system or by an attempt by the government to simulate a perfectly competitive system." The supporting argument given by Arrow in defense of this second statement leaves much to be desired since it assumes that contracts between the insurer and insured that ration the insurance service are somehow outside the competitive system, that the decision to consume more of the service is somehow a "bad" even though the price of the insurance covers the full cost of the service, and, implicitly, that adherence to contractual agreements is not an important feature of the competitive system.

[15] Kenneth J. Arrow, *supra* note 1 at 616.

The centralization of research does provide a more diversified portfolio of investment projects that allows owners to reduce the variance of the outcome of their inventive efforts. To some extent firms do centralize research efforts. But a real social cost is borne if this procedure is pushed too far. The more centralized is the production or financing of invention, the smaller is the degree to which the advantages of specialization can be enjoyed and the less keen is the stimulus offered by competition. These costs must be taken into account in identifying the efficient institutional arrangement, and I suppose that these costs do play a major role in limiting the voluntary centralization of research by industry. The efficient arrangement generally will be one that falls between complete centralization and complete specialization.

It may be that government production or financing of invention is a superior arrangement, in which case extensive use of market arrangements can be criticized. Government *can* take a risk neutral attitude (although I doubt that this is a desirable attitude in the nuclear age). But I do not know what attitude actually will be taken toward risk by government. Government is a group of people, each of whom in the absence of compensation to do otherwise, presumably is risk averse. The psychological propensity to be risk averse, if it is present, is found in employees of government as well as in employees of private enterprise, and a government probably is averse to political risks.

I suspect that the government will be less risk averse in some of its activity. The attempt to place a man on the moon by 1970 probably never will be subjected to careful market measures of risk and rate of return, but if it were, it is unlikely that it would appear worthwhile even if it is successful in the technological sense. In some cases, a technological success carries great weight in achieving political success and here government will be less risk averse.

In other governmental activities, however, the government is likely to behave toward risk in a much more risk-averse fashion than is private enterprise. For example, inventing and innovating a superior postal service, although it has some risk associated with it, seems to be technologically possible and economically promising. But the adverse political developments that could follow from the laying off of many postal employees leads the government to hold back. It is very averse to the risk of being voted out of office.

Arrow's analysis of risk merely states that the market copes with risk differently than it would if risk could be shifted or reduced costlessly, or than it would if people were neither risk averse nor susceptible to moral hazard. But a relevant notion of efficiency must refer to scarcity and people as they are, not as they could be.

In his discussion of the inappropriability of new knowledge, Arrow recog-

nizes that if information is to be produced privately, its producers must be able to realize revenues from the use or sale of information. For this to be possible, information must be appropriable, and Arrow is not optimistic about the ease with which the value of information can be captured by its discoverer. Some part of Arrow's pessimism, I believe, is attributable to his tendency to see special and unique problems in establishing property rights to information when the problems are neither special nor unique.

Appropriability is largely a matter of legal arrangements and the enforcement of these arrangements by private or public means. The degree to which knowledge is privately appropriable can be increased by raising the penalties for patent violations and by increasing resources for policing patent violations.

It is true that all "theft" of information cannot be eliminated at reasonable cost. But knowledge is not unique in this respect, since the same can be said of any valuable asset. The equilibrium price that is paid to producers of automobiles will in part reflect the fact that there is a positive probability that the purchaser will have his automobile stolen. The problem of theft is as pervasive as the problem of moral hazard, and although there may be differences in the cost of reducing the theft of different types of assets there is no difference in principle. It may be argued, as Arrow does, that the ease of theft of knowledge is heightened by the fact that knowledge once used becomes easily known by others. But the theft of an automobile also is made easier when it is removed from the home garage.

One characteristic of knowledge that increases the cost of enforcing private rights is the possibility of stealing information without thereby depriving its owner of the "ability" to use the information, although, of course, the profitability to the owner of using the information may be reduced if the thief uses it. Compared with more tangible assets the detection of the theft of knowledge may need to rely to a greater extent on discovering its subsequent use by others. But if Arrow is correct in asserting that "[t]he very use of information in any productive way is bound to reveal it, at least in part,"[16] then detecting its subsequent use by nonowners may be relatively easy. In any case, the reduction in theft of knowledge can be accomplished, without increasing the probability of detection, by raising the penalties to the thief if he is apprehended. A harsher schedule of penalties always can be used to enhance the appropriability of knowledge.[17]

The truth of the matter is that I, at least, have no more than casual notions

[16] *Id.* at 615. Arrow states this to support his notion that theft of knowledge is easy.

[17] For a definitive analysis of the role of penalties in crime prevention (and of other aspects of the economics of crime), see Gary S. Becker, Crime and Punishment: An Economic Approach, 76 J. Pol. Econ. 169-217 (1968).

about the cost, per dollar value of knowledge, of establishing property rights in information. Given the appropriate legal apparatus and schedule of penalties it may be no more difficult to police property rights in many kinds of knowledge than it is to prevent the theft of automobiles and cash. And even if some kinds of information are more difficult to protect, I am not sure which institutions yield the better solution to the problem or what public policy deduction should be made.

We now turn to what Arrow identifies as the problems of indivisibility (or, in more current terminology, the problem of public goods).

> The cost of transmitting a given body of information is frequently very low. If it were zero, then optimal allocation would obviously call for unlimited distribution of the information without cost. In fact, a given piece of information is by definition an indivisible commodity, and the classical problems of allocation in the presence of indivisibilities appear here. . . .[18]
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> As we have seen, information is a commodity with peculiar attributes, particularly embarrassing for the achievement of optimal allocation. . . . [A]ny information obtained . . . should, from the welfare point of view, be available free of charge (apart from the cost of transmitting information). This insures optimal utilization of the information but of course provides no incentive for investment in research. In an ideal socialist economy, the reward for invention would be completely separated from any charge to the users of information. In a free enterprise economy, inventive activity is supported by using the invention to create property rights; precisely to the extent that it is successful, there is an underutilization of the information.[19]

The partitioning of economic activity into the act of producing knowledge and the act of disseminating already produced knowledge is bound to cause confusion when the attempt is made to judge efficiency. It is hardly useful to say that there is "underutilization" of information if the method recommended to avoid "underutilization" discourages the research required to produce the information. These two activities simply cannot be judged independently. Since one of the main functions of paying a positive price is to encourage others to invest the resources needed to sustain a continuing flow of production, the efficiency with which the existing stock of goods or information is used cannot be judged without examining the effects on production.

If, somehow, we knew how much and what types of information it would be desirable to produce, then we could administer production independently of the distribution of any given stock of information. But we do not know these things. Arrow's assertion that "[i]n an ideal socialist economy, the reward for invention would be completely separated from any charge to the users

[18] Kenneth J. Arrow, *supra* note 1, at 614-15.

[19] *Id.* at 616-17.

of information" begs this whole problem. How would such a system produce information on the desired directions of investment and on the quantities of resources that should be committed to invention? There are ways, of course. Surveys of scientists and managers could be taken and a weighting scheme could be applied to the opinions received; no doubt there are many other ways of making such decisions. But the practice of creating property rights in information and allowing its sale is not clearly inefficient in comparison with these real alternatives.

Arrow does acknowledge the adverse incentive effects that would obtain in a private enterprise economy if information were made freely available, but this does not deter him from asserting that the capitalistic method is inefficient in its distribution of information. This ambiguity and looseness in Arrow's analysis is attributable directly to his viewpoint and approach. If he were to compare a real socialist system with a real capitalistic system the advantages and disadvantages of each would stand out, and it would be possible to make some overall judgment as to which of the two is better. But Arrow compares the workings of a capitalistic system with a Pareto norm that lends itself to static analysis of allocation but, nonetheless, that is poorly designed for analyzing dynamic problems of production. He finds the capitalistic system defective. The socialist ideal, however, resolves static allocation problems rather neatly. But this is only because all the dynamic problems of production are ignored. The comparison of a real capitalistic system with an ideal socialist system that ignores important problems is not a promising way to shed light on how to design institutional arrangements for the production and distribution of knowledge.

Indivisibilities in the use of knowledge become important only when the costs of contracting are relatively large. This point generally has been ignored. If everyone is allowed the right to use already available knowledge because one person's use of existing knowledge does not reduce its availability to others, there will tend to be underinvestment in the production of knowledge because the discoverer of knowledge will not enjoy property rights in the knowledge. But this underinvestment works to the disadvantage of others who would have the output of any additional investment made available to them at no cost. If the cost of contracting were zero, these prospective "freeloaders" would be willing to pay researchers to increase the investment being made. Research activity would be purchased just as any other good.

The relevance of contracting cost is most clearly seen by supposing that there are two prospective freeloaders and one inventor. If the freeloaders are allowed to use successful research without paying the inventor, he will reduce his research efforts. But then the two freeloaders will find it in their interest to buy additional research effort from the researcher. The only implication of indivisibilities in the use of information is that it will pay for the freeloaders

to join forces in buying this additional research, for by doing so they can share the required payment. If the cost of arriving at such an agreement is negligible, the resources devoted to experimentation will be the same as if the freeloaders were *required* to pay a fee to the inventor for the use of his successful experiments.

The objective of bargaining between those who produce knowledge and those who use it, whether the researcher has rights to the knowledge he produces or whether this knowledge is freely made available to all, is the production of knowledge at efficient rates. For if knowledge is produced at efficient rates, the social value of the research effort will be maximized. The bargaining between the interested parties will determine how this value is shared. If the cost of contracting, broadly interpreted, is zero, it will be in everyone's interest to reach an agreement that maximizes the value of the research effort because all will have a larger pie to share.

If the cost of contracting is positive, the kind of property rights system that is established may change the allocation of resources in the production of knowledge. If freeloading is allowed, that is, if users of knowledge are given the right to knowledge without paying for it, some prospective users will be inclined to stay out of any cooperative agreement between users. There will be an incentive to users jointly to pay researchers to increase the resources being committed to research, but if some users can remain outside this cooperative effort, they stand to benefit from research paid for by other users. This may lead to an underinvestment (underpurchase?) in research.

It might seem that the tendency for a user to remain outside any cooperative purchasing effort is independent of contracting costs. But this is not so. Broadly interpreted, such costs will include not only the cost of striking a bargain but also the cost of enforcing any bargain that is made. The property rights system that makes produced information freely available to all increases the cost of enforcing agreements. Let the user's purchasing organization attempt to acquire members. What does it have to offer prospective members? It cannot guarantee that those who join will have exclusive rights to the research output purchased, for the law says that anyone can use knowledge. The cost of enforcing a contract that promises exclusivity in the use of whatever knowledge is purchased is raised inordinately by this public policy, and that is why there will be a strong inclination to remain outside the buyer's cooperative effort.

If the legal system is changed so that producers of research have property rights in their research output, they will be able to transfer legal title to purchasers who can then exclude nonpurchasers from the use of the research. The incentive to remain a nonpurchaser is diminished with private appropriation of knowledge precisely because the cost of enforcing exclusive contracts is reduced.

The last assertion in the above quotation from Arrow's paper, "In a free enterprise economy, inventive activity is supported by using the invention to create property rights; precisely to the extent that it is successful, there is an underutilization of the information," does not constitute an argument against the creation of property rights. The indivisibility problem may very well be handled best by a private property system that reduces the cost of contracting and raises the cost of free-loading while, at the same time, it provides incentives and guidance for investment in producing information.

III

The problem discussed in this section is qualitatively different from those discussed above. Here our attention is directed to the structure of the industry in which the knowledge is used.[20] Arrow discusses the relevance of industry structure in that section of his paper subtitled Competition, Monopoly, and the Incentive to Innovate. The objectives and conclusions are stated by Arrow as follows:

> I will examine here the incentives to invent for monopolistic and competitive markets, that is, I will compare the potential profits from an invention with the costs. The difficulty of appropriating the information will be ignored; the remaining problem is that of indivisibility in use, an inherent property of information. A competitive situation here will mean one in which the industry produces under competitive conditions, while the inventor can set an arbitrary royalty for the use of his invention. In the monopolistic situation, it will be assumed that only the monopoly itself can invent. Thus a monopoly is understood here to mean barriers to entry; a situation of temporary monopoly, due perhaps to a previous innovation, which does not prevent the entrance of new firms with innovations of their own, is to be regarded as more nearly competitive than monopolistic for the purpose of this analysis. It will be argued that the incentive to invent is less under monopolistic than under competitive conditions but even in the latter case it will be less than is socially desirable.[21]

Arrow arrives at these conclusions under the two varieties of circumstances that are implied by the way in which the problem is set up.

We will assume constant costs both before and after the invention, the unit costs being c before the invention and $c' < c$ afterward. The competitive price before invention will therefore be c. Let the corresponding demand be x_c. If r is the level of unit royalties, the competitive price after the invention will be $c' + r$, but this

[20] I am indebted to Professor Aaron Director for sharing with me his revealing insights into the problem discussed in this section, and, in particular, for suggesting that the results of Arrow's analysis are affected significantly by the difference in scale between the competitive industry and monopoly industry that is implicit in his approach. I would also like to thank Professor George J. Stigler for his critical review of an earlier draft.

[21] Kenneth J. Arrow, *supra* note 1, at 619.

cannot of course be higher than c, since firms are always free to produce with the old methods.[22]

The basic point at issue can be brought forward best by discussing the circumstance in which $c' + r$ is less than c if the royalty is set at its profit maximizing level.

Arrow's argument can be put into geometric form with the aid of Figure I. Let c and c′, respectively, be the per unit cost of production before and

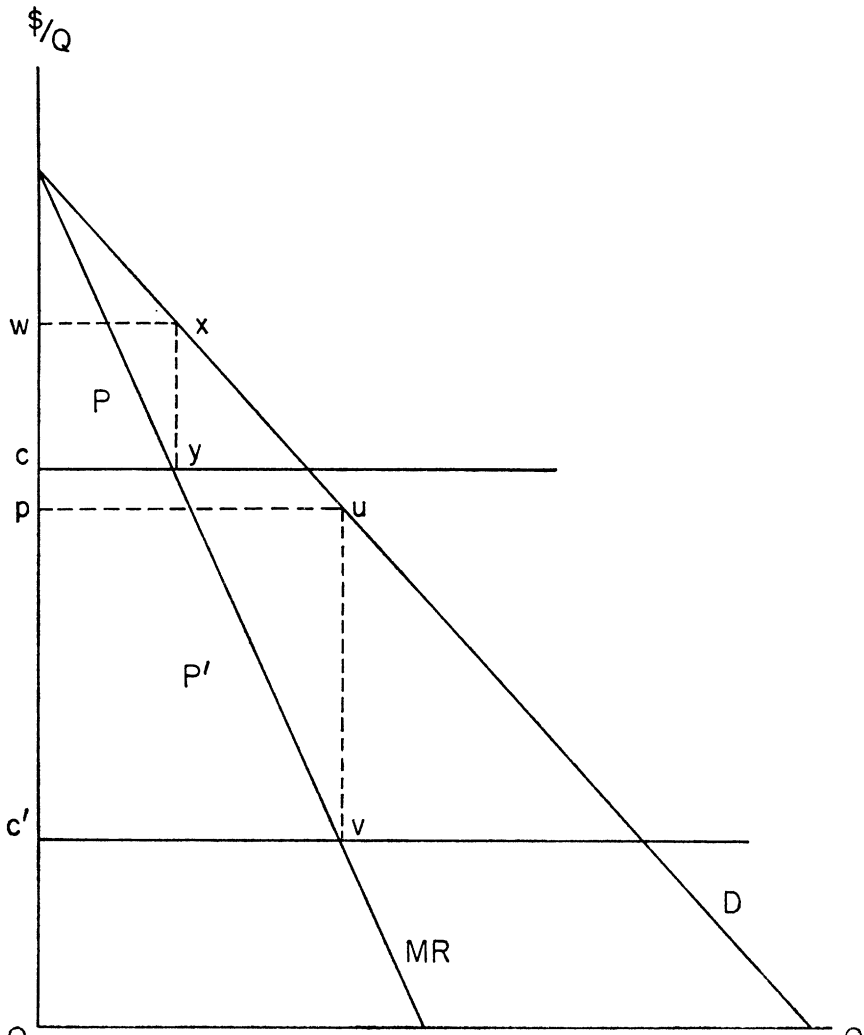

FIGURE I

[22] *Id.* at 620.

after the invention. The inventor selling to a competitive industry sets the per unit royalty, r, so as to maximize the size of the rectangle c′puv; that is, the inventor sets the royalty so that the quantity demand is where marginal revenue, MR, is equal to c′. This results in a price for the competitive industry's product equal to p. Following Arrow's terminology, let $P' = c'puv$. An inventor selling to the competitive industry illustrated in Figure I would be willing to invest in inventing so long as the cost of the invention to him is less than P′.

Arrow, in posing the alternative situation in which the industry is a monopoly owned by the inventor reasons that before the invention the inventor, acting as would any monopolist, has set price at w to hold the quantity demanded to that rate of output for which $c = MR$. His profit, P, equals rectangle cwxy. After his invention, his cost per unit will be lowered from c to c′. Maximizing profits with his new cost he will set price at p. This yields a new profit rectangle equal to P′. The basic conclusion reached by Arrow, that "the incentive to invest is less under monopolistic than under competitive conditions," is now clear. The inventor selling to a competitive industry would be willing to invent if his cost is less than P′ but the inventor who is a monopolist in the product market would be willing to invent only if the cost of inventing is less than $P' - P$, for this precisely measures to him the increase in profits attributable to the invention. Since $P' - P$ always is less than P′, Arrow concludes that the incentive to invent is less under monopoly.

Arrow's conclusion, however, does not lend itself to a clear interpretation since he has allowed two extraneous issues to influence his analysis. (1) Arrow's inventor not only produces an invention but, in addition, he possesses the monopoly power to discriminate in the royalty charges he sets for the two industries. (2) Arrow neglects to take account of the normal monopoly incentives in the monopoly purchasing the invention; monopoly models generally deduce that a monopolist will use less of all inputs, including an invention, because he produces less output; the demonstration of any *special* effect of monopoly on the incentive to invention requires that adjustments be made for this normally restrictive monopoly behavior. When proper account is taken of these two matters we find that Arrow's conclusions are false.

Let us suppose that competitive inventions or regulations restrict the inventor to charging all users of the invention identical unit royalties, and let $p - c'$ in Figure I measure that royalty. In this case, both the competitive industry and the monopolist accept $p - c'$ as the price of an input. The competitive industry would then pay a total royalty equal to P′ to the inventor while the monopoly would pay half this amount since the monopoly's output would increase only to the intersection of pu with MR. The monopoly does offer to pay less total royalty because it produces at a smaller output

rate than does the competitive industry. This comes as no surprise. One of the better known deductions in economics is that a nondiscriminating monopolist will sell fewer units of output and use fewer units of input than would be used in the same industry if it were competitively organized.

To remove from the analysis the normal restrictive effect of monopoly on output, let us define MR in Figure I to be the demand curve facing the competitive industry. For any given unit cost, both the monopoly and the competitive industry will produce the same output rate. At a royalty per unit equal to p — c′ both industries will produce where pu intersects MR and both will pay the same total royalty to the inventor.

By eliminating the inventor's monopoly power to charge different royalties and simultaneously by adjusting the demand curve facing the competitive industry to eliminate the normal restrictive effect of monopoly on input use, we arrive at the conclusion that a competitive industry will offer no greater incentive to invention than a monopoly. There is no special adverse effect of monopoly on the incentive to invention.

Let us now consider the case where rivalry between inventors, or where regulation fails to equalize the royalties. What will be the incentive to invention offered by the two industries after adjusting their sizes to remove the normal restrictive effects of a prior monopoly? We shall see that in this case the incentive to invention is just the reverse of what Arrow concluded; for industries that would operate at the same levels of output in the absence of the invention, the development of a monopoly invention with price discriminating power will receive greater rewards from a buying industry that is a monopoly.

In Figure II let D_m and MR_m be the demand and marginal revenue facing the monopolist and let D_c and MR_c characterize the industry demand facing the competitive industry. Assume that $MR_m = D_c$ so that for any given constant unit cost both industries will produce the same output rates. At cost = c the competitive industry produces output cu, since demand must equal marginal cost under competition, while for monopoly the output rate cu will be selected because marginal cost must equal marginal revenue. Hence, the size of the two industries will be the same for any given constant unit cost. The effect of monopoly on the size of output has been removed.

At cost c, the monopoly receives profit P = cptu, whereas with the cost reducing invention the monopoly profit is P″ = c′p′yx. The incentive to monopoly invention given by the monopoly industry is P″ — P. The best that the inventor can do if he sells his monopoly invention to an *equal sized* competitive industry is to ask a per unit royalty equal to p′ — c′ for this will cause the competitive industry to produce an output rate p′v that maximizes the inventor's total royalty c′p′vw. We wish to ascertain whether the incen-

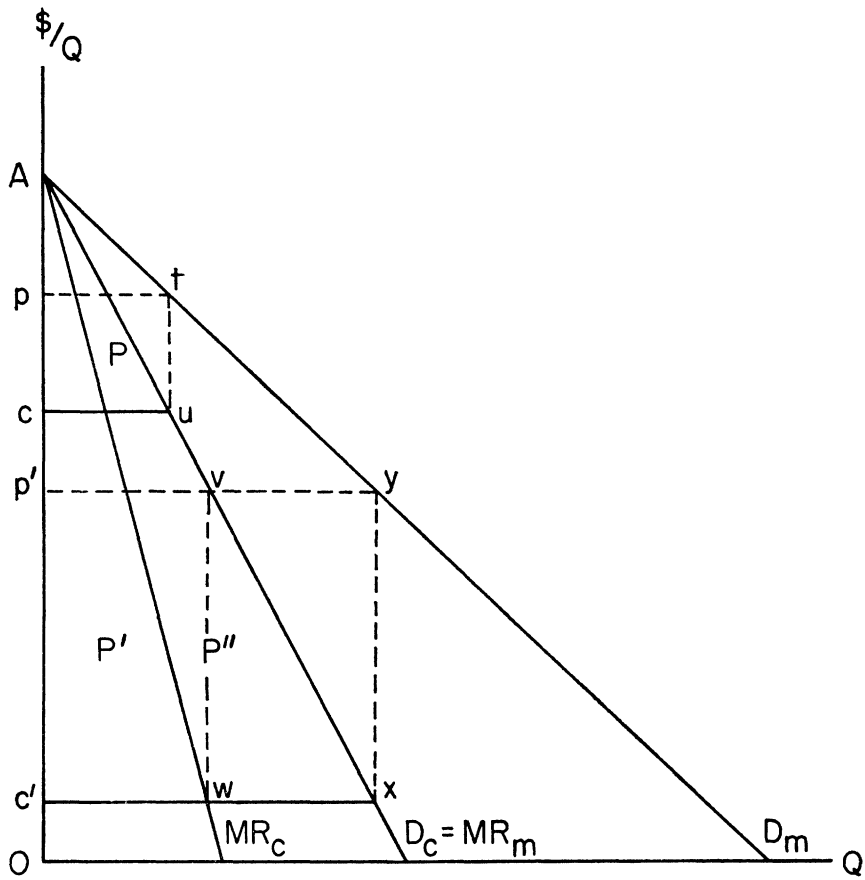

FIGURE II

tive to invention offered by the competitive industry, c′p′vw = P′ is larger or smaller than P″ — P. Figure II indicates that the incentive to invention offered by the competitive industry is smaller since P″ — P′ clearly is greater than P. However, to make sure that this is no geometrical illusion, the reader will find an algebraic proof for the linear case in the Appendix. The Appendix also presents a counter example to Arrow's conclusion for a case where both industries start at the same output rate and confront the same demand curve.

The traditional belief that monopoly restricts output may suggest that some measure of antitrust is desirable. If Arrow's analysis is taken to suggest, as I think it must, that there are special adverse effects of monopoly on the incentive to invention, a framer of public policy would deduce that antitrust should be pursued more diligently than is dictated by considerations of output restrictions only. But he would be wrong. If it is thought desirable to

encourage invention by granting monopoly power through the patent or through secrecy, the above analysis suggests that antitrust should be pursued less diligently than is dictated by considerations of output restrictions only, for, at least in the linear model of two industries of equal output size, the more monopolistic will give the greatest encouragement to invention.

IV

The problem of efficiency and the possibilities of achieving efficiency through reform were associated historically with the grant of monopoly and tariff privileges by governments. In their historical settings, criticisms of inefficiency took on the characteristic of the comparative institution and not the nirvana approach. Critics of governmental policies who asked for reform were seeking to substitute an institutional arrangement that was both real and fairly well understood. They were confident of the beneficial results and of the practicality of allowing market enterprise to allocate resources. And, although the operation of political forces had not been subjected to the same careful study, the critics did know what they expected if governmentally created protection from those market forces were removed.

A process of refining the analytical concept of competition then set in, culminating in the currently accepted necessary conditions for perfect competition. These conditions, of course, can be only approximated by real institutions. On top of these are placed additional conditions on the nature of production, commodities, and preferences that are necessary if the equivalence of perfect competition and Pareto efficiency is to be established.

While the application of these conceptual refinements is an aid to solving some economic problems, especially in positive economics, their application to normative problems has led to serious errors. If an economy has no serious indivisibilities, if information is complete, etc., then the modern analysis can describe the characteristics of an efficient long-run equilibrium; this description is the main result of modern welfare analysis. But modern analysis has yet to describe efficiency in a world where indivisibilities are present and knowledge is costly to produce. To say that private enterprise is inefficient because indivisibilities and imperfect knowledge are part of life, or because people are susceptible to the human weaknesses subsumed in the term moral hazards, or because marketing commodity-options is not costless, or because persons are risk-averse, is to say little more than that the competitive equilibrium would be different if these were not the facts of life. But, if they are the facts of life, if, that is, they cannot be erased from life at zero cost, then truly efficient institutions will yield different long-run equilibrium conditions than those now used to describe the ideal norm.

It is one thing to suggest that wealth will increase with the removal of legal

monopoly. It is quite another to suggest that indivisibilities and moral hazards should be handled through nonmarket arrangements. The first suggestion is based on two credible assumptions, that the monopoly can be eliminated and that the practical institutional arrangement for accomplishing this, market competition, operates in fairly predictable ways. The second assertion cannot claim to have eliminated indivisibilities, risk-averse psychology, moral hazard, or costly negotiations, nor can it yet claim to predict the behavior of the governmental institutions that are suggested as replacements for the market.

I have stated elsewhere what I believe to be the basic problem facing public and private policy: the design of institutional arrangements that provide incentives to encourage experimentation (including the development of new products, new knowledge, new reputations, and new ways of organizing activities) without overly insulating these experiments from the ultimate test of survival. In the context of the problems discussed in Arrow's paper, these institutional arrangements must strive to balance three objectives. A wide variety of experimentation should be encouraged, investment should be channeled into promising varieties of experimentation and away from unpromising varieties, and the new knowledge that is acquired should be employed extensively. No known institutional arrangement can simultaneously maximize the degree to which each of these objectives is achieved. A difficult-to-achieve balance is sought between the returns that can be earned by additional experimentation, by giving directional guidance to investment in experimentation, and by reducing the cost of producing goods through the use of existing knowledge. The concepts of perfect competition and Pareto optimality simply are unable at present to give much help in achieving this balance.

APPENDIX

All notation is consistent with Figure II of the text. In this part of the Appendix we allow the inventor to produce a monopoly invention that he markets to a monopoly and a competitive industry. The industries are defined so that at any given marginal cost the rates of output will be the same.

(1) $P = A - Bq$ be monopoly demand, then total revenue is
(2) $TR = Aq - Bq^2$ and marginal revenue is
(3) $MR_m = A - 2Bq$.

At unit cost c, the monopoly maximizes profits where

(4) $c = MR_m = A - 2Bq$, which allows us to calculate monopoly output as
(5) $q = \frac{A - c}{2B}$.

Monopoly profit at c cost is

(6) $P = TR - cq = \frac{(A - c)^2}{4B}$ and the incentive to invention with monopoly is

(7) $P'' - P = \frac{(A - c')^2 - (A - c)^2}{4B}$ where c' is the new lower unit cost.

Under competition, the inventor calculates the marginal revenue associated with the industry demand curve

(8) $D_c = MR_m = A - 2Bq$, so that
(9) $MR_c = A - 4Bq$.

The inventor then selects that per unit royalty such that the resulting output rate is where $c' = MR_c$. That is, where

(10) $c' = A - 4Bq$. The competitive industry's output rate will then be

(11) $q = \frac{A - c'}{4B}$ and the incentive to invention is

(12) $P' = (A - c')q - 2Bq^2 = \frac{(A - c')^2}{8B}$.

Comparing $P'' - P$, from (7), to P', we find that P' must always be less in the case under consideration since

$$(P'' - P) - P' = (A - c') - 2(A - c)$$

and

$$(A - c') > 2(A - c) \text{ if } p' < c.$$

The Arrow proposition is incorrect even if less acceptable but more lenient restrictions are considered. Again, let us assume that the inventor has a monopoly, but let both the competitive industry and the monopoly face the same demand curve. However, assume that the initial per unit cost, k, in the competitive industry is sufficiently above the monopoly's initial cost, c, to yield the same preinvention output rates. Then, let the cost in each industry be reduced by the same amount as a result of the invention. In this way, we pose a situation in which initial output levels are the same but one in which the invention moves both industries along identical demand curves. An arithmetic counterexample of Arrow's proposition follows.

Let the demand curve facing both industries be

(1) $$p = 100 - q$$

Marginal revenue then is

(2) $$MR = 100 - 2q$$

Let $c = \$90$ and $c' = 10$; and in each instance equate marginal revenue to marginal cost to derive the monopoly profit maximizing q's:

$$(3) \quad \begin{matrix} 90 = 100 - 2q \\ q = 5 \end{matrix} \qquad (3') \quad \begin{matrix} 10 = 100 - 2q \\ q = 45 \end{matrix}$$

Profit P at $q = 5$ and P'' at $q + 45$ are

$$(4) \quad p = 100 - 5 = \$95 \qquad (4') \quad p' = 100 - 45 = \$55$$

$$(5) \quad P = (\$95 - 90)\ 5 = \$25 \qquad (5') \quad P'' = (\$55 - 10)\ 45 = \$2025$$

The amount that the monopolist would be willing to pay for this cost reducing invention is $P'' - P = \$2000$.

We now wish to compare this with the rate of return to invention for a competitively organized industry of the same initial scale as the monopoly. To accomplish this while using the same market demand curve, $p = 100 - q$, let us set the competitive industry's preinvention per unit and marginal cost, k, at a high enough level to generate an output rate equal to the initial monopoly output rate of $q = 5$. Since the competitive industry will produce that output rate where $p = mc$, k must be \$95. Now let the invention reduce this cost by the same absolute magnitude as $c - c' = \$80$. For the competitive industry, then, the post invention marginal cost, k', will be $\$95 - \$80 = \$15$.

The inventor now will pick a per unit royalty such that the competitive industry will produce where $k' = MR$ for this will result in the largest possible total royalty payment. Using equation (2), we find this output rate to be

$$(6) \quad 15 = 100 - 2q; \qquad q = 42.50$$

The inventor's royalty per unit will be the difference between price and $k' = 15$. From equation (1), we find that $p = \$57.50$ (at $q = 42.50$), so that the inventor's total royalty in the competitive case, P', will be

$$(7) \quad P' = (57.50 - \$15)\ 42.50 = \$1806.25$$

and we find that this is \$193.75 *less* than the inventor could have earned if he sold the invention to a monopoly of the same initial size.[1]

[1] If this problem is repeated for the same percentage reductions in cost for the monopoly and the competitive industry, we would find that the incentives to invention would be equally great.