Conditions for the Successful Use of Science

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Summary. There is ground for concern that the British research and development effort, which is of considerable size, may not be well distributed. In some areas of intense scientific effort, commercial priorities tend to be forgotten. Too many of the units of the economic system are backward in understanding what science can offer and inefficient in using the opportunities which it provides. Evidence suggests that the successful use of science depends on the overall quality of management rather than specifically on its degree of scientific knowledge.

My presence at this meeting of the British Association for the Advancement of Science may be attributed to Charles Babbage, whose criticisms of the Royal Society were influential in the founding of this Association, and who with Malthus and Richard Jones helped to give it in its earliest days a Section F, first called Statistics, then Economic Science and Statistics, and now Economics. One must remember that in the 1830's the word "statistics" meant the collection, classification, and discussion of facts bearing on the condition of a state or community. These facts were often numerical, but there was no implication of their sophisticated mathematical manipulation. It was believed that the establishment of the plain facts would guide the statesman and preserve him from errors of policy, just as the establishment of medical knowledge would preserve the doctor from error; and so statistics could be a "science" in the same way as medicine. Such beliefs we now see to be quaint 19th-century optimism; and perhaps the more austere natural scientists were right to doubt, as they did on several occasions, the suitability of such subjects as statistics and economics for a scientific association, especially as they attracted frivolous persons such as women. However, let us not waste time inquiring whether the social sciences are sciences. The important thing is that the Association's tolerance, for a century and a half, of the serious study of society has provided it with an interface between the natural sciences and the society which they have so greatly affected. My discussion here is concerned with matters at that interface.

Babbage's *Reflections on the Decline of Science in England and on Some of its Causes* was published in 1830. His evidence for a decline of science was, in effect, that persons of other nations were having the temerity to make discoveries—thus failing to act in the spirit of Milton's words, that God reveals himself "as His manner is, first to His Englishmen." His real complaint, however, was that science was the plaything of aristocrats, whereas it needed to be a serious profession in close and stimulating contact with those who would apply it. In his book *On the Economy of Machinery and Manufactures* (1832) he writes of the newly founded British Association:

> But perhaps the greatest benefit which will accrue from these assemblies, is the intercourse which they cannot fail to promote between the different classes of society. The men of science will derive practical information from the great manufacturers.

You will note the direction of the stimulus which he names first.

There is no doubt that science is now a serious profession or group of professions, on a scale far beyond anything of which the 19th century could have dreamed. But professions often derive their sense of belonging together in part from the erection of barriers against the outside world. There is reason to question whether professional scientists in Britain today are in sufficiently close and stimulating contact with the needs and problems of those who could use the results of science. Indeed, the British Association—returning to its first inspiration—sees a need to give an increasing place in future meetings to the promotion of an intercourse with the users of science in the present-day economy and society. For it has become very evident that you cannot have a healthy science in a sick economy; however pure his work and however high his tower of ivory, the scientist depends for his support and success on the creation of wealth within an ordered society.

Direction of Research and Development

Britain is only a small part of the world of science, and it is unreasonable to expect the use of science to be greatly dependent on our scientific discoveries. What does matter is the possession of those who can understand and draw in new ideas from all over the world. The Japanese are notable for their insatiable curiosity about other people's ideas, and the earlier stages of their extraordinary advance were achieved without any great contribution from their own scientific discovery. But a country can best have people with quick knowledge and understanding of what is going on at the frontiers of science by itself promoting work at those frontiers; for ideas pass most readily in the first place between fellow workers in the same field. It is in this sense that there is economic justification for a broadly based effort in pure science, which can provide the listening stations for what is going on in the way of new discovery, whether or not it is also a large contributor to that discovery. But, from the standpoint of the economist, it is possible to have too much pure science. High ability is in short supply, and if too much of it is used for basic or pure research there may be too little to sustain effective application.

If, however, we trace the way from fundamental ideas to specific applications, it is often long and tortuous; it usually consists, in fact, of several different paths, whose convergence makes the application possible. Some of these paths may originate in the industrial arts rather than in the scientist's laboratory. The process of applied R & D, which takes ideas through to the point when a product can successfully be launched on the market, is not always identifiable as a separate and purposive activity which enters the national statistics of R & D. Smaller firms cannot afford to maintain R & D as a separate function, but this does not mean that they are always de-

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pendent on others for their innovation. In particular, they may buy in the results of science in an intermediate form, embodied in a machine, material, or method offered by a supplier, and then use their ingenuity in finding a new use for what is supplied. Thus, many small electronics firms are genuine innovators, but their innovations depend on what the major chip manufacturers can offer. Even in large firms, with their own R & D departments, significant innovation may take place elsewhere in the organization.

All this makes it rather difficult to interpret the data on R & D expenditure; which is fortunate, since the evidence for a relation between the size of that expenditure and economic success is, to say the least of it, elusive. What matters, of course, is that the R & D effort should be sensibly directed to purposes which are important in relation to national need. Much of it will be unsuccessful—that is, its product will be the discovery that something cannot be done, or cannot be done at an economical price, or has missed its market opportunity. But an effort that is badly directed or badly balanced will contain an undue proportion of failures.

Britain is recorded as spending over 2 percent of its gross national product on R & D, which is relatively high. But a third of this is on defense, and must seek its own special justification; arguments from "spin off" are not well founded. The rest is very unevenly spread, with a heavy concentration (encouraged by government support or direction) on the aerospace, nuclear energy, and communications industries, and a general tendency to favor chemicals and electrical and electronic engineering. There are large areas of manufacturing, commerce, finance, and the public services for which the recorded research effort is tiny in relation to their output. Now, of course, any R & D program will appear uneven, both because the opportunities for the use of science are greater in some areas than others, and because the costs of development are much higher with some technologies than with others. But it strains belief to suppose that the British effort is optimally distributed; if it were, we would surely have (with a program of this size) more industries that are successful in keeping up with the product specifications and technology of their rivals.

The Need for Toughness

I suggest that there are two major faults. One is that, in some of the areas of intense scientific effort, we are too ambitious and insufficiently hard-headed. We are inspired by the vision of a great leap in technology, achieved by British brains alone, which will put us ahead of the world and enable us to command a market whose existence or precise extent we have not carefully considered. But the progress of technology is more like that of a beetle than a kangaroo; the simile is apt, since the Volkswagen Beetle was a remarkable example of market dominance achieved by small steps of improvement over a long period. The Japanese, by taking a series of well-judged steps to improve their telecommunications system, will probably get further and faster than British Telecom's integrated program for System X. To the traveler by rail, it is more important to be confident about a time of arrival than to be able to do a journey a little quicker; it was not, therefore, very hard-headed to attempt a kangaroo leap to the Advanced Passenger Train at a time when much simpler applications of science could have improved the reliability of the system. Other examples can be given, even without mentioning Concorde.

Understanding What Science Can Offer

The other fault is that far too many of the units of the economic system—I use this phrase because I want to include departments of central and local government as well as firms—are backward in understanding what science can offer, and inefficient in using the opportunities which it provides. You will note that this affects the economy in two ways, first by impeding the appearance of innovation, and second by slowing down its diffusion when it has appeared. Let me take an example. No one in possession of their faculties can possibly be unaware of the microelectronics revolution. It is the subject of a considerable information campaign by government; it is much covered by the media; the consequences have an evident impact on daily living. Yet in 1981 about 70 percent of manufacturing establishments employing 20 or more people in Britain (representing about 45 percent of total employment in manufacturing) had no applications in either products or processes. About half the nonusers see no scope for applications, and many of these are probably wrong. The other half see some scope, but had not yet acted; of these, 37 percent for product applications and 24 percent for process applications think that their overseas competitors are already using microelectronics. Among the British users, more think themselves to be behind their overseas competitors than consider they are ahead (*1*).

This is an extreme example, because the technology is so pervasive that one would expect even firms of a modest size to have multiple uses for it. But if you go to other areas of the application of science, the story is often the same: too little and too slow. How can this be? Do we have to change people, or change the environment within which they operate?

A quarter of a century ago, Sir Bruce Williams and I did some work with the Science and Industry Committee (of which the Association was a sponsor). Three of our conclusions were (*2*):

> 1) Technical progressiveness is related to the general quality of the firm; and attention to other aspects of its general quality—for instance, to management efficiency or to salesmanship and market research—helps to create the conditions for technical progress. In other words, the use of science is not an optional extra to be attached to the firm, but an expression of the whole attitude of the firm.
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> 2) Effective industrial research and development must be closely related to production and sales policy and needs. . . . Those who manage research must be able to judge the possibilities of projects on economic as well as scientific grounds.
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> 3) The interconnections of firms are important. . . . Hence there is a danger to the progress, not just of one firm, but of a whole chain of firms, when one company is "parochial" in its attitude—self-satisfied, surrounded by the barriers of ignorance, complacency and secrecy.

The Quality of Management

What this implies—though we did not make the point as forcibly as we might have done—is that the successful use of science depends on the quality of management, from which derive the attitudes of the firm and the quality of its various actions. It is not implied that the senior management should themselves be qualified scientists, though they must have enough sympathetic understanding of the areas of science relevant to the work to be able to make sensible judgments on what the experts recommend to them. But equally they need a sympathetic understanding of marketing, of production engineering and systems planning, of finance, of personnel relations; it is a mistake to suppose that you get a balanced policy by linking together a set of narrow and blinkered experts in the areas of the firm's actions. Somewhere, the progressive firm needs the integrating personality who possesses "breadth," that is, an ability to make wise judgments which affect several parts of the activity of his (or her) company.

This, then, is one aspect of the elusive term "quality"; it reminds one of John Maynard Keynes' eloquent description of the combination of gifts needed by a master economist (*3*):

> He must reach a high standard in several different directions and must combine talents not often found together. . . . He must understand symbols and speak in words. He must contemplate the particular in terms of the general, and touch abstract and concrete in the same flight of thought. He must study the present in the light of the past for the purposes of the future. No part of man's nature or his institutions must be entirely outside his regard.

If I had to put in a single word another aspect of the quality of management, I would use the word "toughness." This is not intended to imply a propensity to be nasty to trade unions. What I mean is a readiness to face the facts of a firm's position, to analyze them in a careful and rigorous way, to hold on to a problem with tenacity until it is solved, to delay only when there is good reason for delay, to take the calculated risk of timely action on partial information rather than wait for an unattainable certainty. Sloppy analysis, facts ignored, decisions evaded or fudged—all these are enemies of the successful use of science.

Any living economy contains some units which are growing and succeeding, and others which are dying; in Alfred Marshall's image, like trees of the forest, though he added a reference to "vast joint-stock companies, which often stagnate, but do not readily die" (*4*). The recent record of the British economy, and in particular the loss of some whole industries and the failure to keep up with advanced technology in others, suggests that our forestry is imperfect: or, to change the metaphor, that we have the wrong ratio of lame ducks to swans. If I am right in supposing that part of the problem is an inadequate supply of managers of breadth and toughness, capable of managing progressive firms and of using scientific knowledge wisely, this could have four different causes. The first I will dismiss as disrespectful to my audience, and anyway incapable of proof at present: namely, that for some reason of genetics the British stock is declining in the relevant abilities—briefly, that we are Thick. The second possible cause is a misallocation of ability. If all clever people became poets, and stupid ones produced food, clothing, and other material goods, it is likely that the poets would find themselves hungry. There is unhappily some reason to suspect a bias in British society, and in education, which is unfavorable to wealth-producing activities but highly favorable to the activities which are seen as socially significant but which depend on wealth-producing for their support. The schoolmaster who turned round after a factory visit and said "That's where you'll end up if you don't pass your 'A-levels' " is probably imaginary, but the idea has an uncomfortable familiarity. It appears that there is a good flow of ability into the finance industry, and we have no reason to fear international comparisons in distribution or in agriculture; but the supposition that for a long period manufacturing has not attracted enough people of quality to ensure its success is a plausible one. If I were asked to name a single measure which in the long run might help to alter this, it would be to stop recruiting teachers who have never worked outside an educational institution.

A third possible cause is that, within industry, we select against those with qualities of breadth and toughness, and in favor of the safe company man who can be relied on not to subject his colleagues to the inconvenience of a new idea. This is a very likely way for an organization to act, and particularly so if it is a large and stagnant organization. It is relevant here to observe that Britain has an unusually high ratio of large to small firms, the consequence of decades in which we believed that Big was Beautiful, and in which mergers were fashionable and small firms got little encouragement. It would be healthier if managers of quality could more readily exercise and develop their abilities in smaller firms. My fourth possible cause for inadequate quality in managers is that our systems for training and educating them are insufficiently rigorous and demanding; that they instill the ideas of muddling through or hoping for the best, rather than those of systematic conquest of difficult objectives.

The Business Environment

Whatever combination of these causes may be operating, the result is, I believe, that too large a part of our economy is starved of the abilities of management necessary to enable it to be progressive; and this is inimical to the successful use of science. However, there is another line of argument, which blames not the managers but the business environment within which they operate. It is observed that British managers operating overseas are often highly successful (though this, of course, could be because they are a specially selected group); and that foreign managers operating in Britain do not often turn up results which stand far above those of their British rivals. It is not asserted that the environment is so unfavorable that no one can succeed—that is plainly untrue—but that it reduces the probability of success, and thereby affects the lame duck/swan ratio.

This is a highly pessimistic theory, since the difficulties of the business environment must be supposed to be, at least in part, caused by economic ill-success, which thus becomes self-perpetuating. Bruce Williams and I (*2*, p. 2) referred to this as having "something of the nightmare quality of running up a descending escalator." Few of us, however, would be willing to accept the view that it is impossible to break out of a spiral of ill success. Some, perhaps the greater part, of the sickness of the economic body which we ascribe to the general business environment is psychosomatic; we have become, as a nation, markedly pessimistic in our assessment of the future, and our predictions become self-fulfilling. The United States has a growth rate of productivity even worse than ours, but American businessmen are conditioned to believe that they live in a system so excellent that victory over their problems is inevitable. The British urgently need to follow up the surprising discovery that we are exceedingly efficient at fighting minor wars by showing a similar confident efficiency in dealing with other problems, including those which relate to the peaceful use of science.

There is no doubt, of course, that a long period of relative ill-success does produce real as well as imaginary problems. There is no ground for a foolish optimism. But it would be a great help to all who have to manage change if we could occasionally admit the possibility that we do some things rather well, and that spirals can be virtuous as well as vicious. The achievement of this change in psychology is a function of leadership, but leadership is not something which is solely to be exercised by government. Many individuals and bodies have a part to play; and not least the British Association, which can help to spread the news of the successes of applied science and of the great possibilities which still lie ahead.

Diversion of Managerial Energy

But, apart from the general sense of depression and failure, are there specific things in the business environment which are preventing the successful use of science? Not high taxation: British taxation is not particularly high, and its treatment of industry is relatively generous. In some places, perhaps, there may be the wrong balance between competi-

tion and safety, but this varies so much from industry to industry that it cannot be a general fault. Not the spirit of Ned Lud (*5*); the evidence for any general obstruction to technical progress caused by the attitudes of workers is very thin indeed, and is not established by quoting isolated cases.

By stating part of the problem in terms of diversion of managerial energy from the main business of managing, I can conveniently insert a commercial for my presidential address to Section F in 1961, "The economic use of brains" (*6*). I see two possible reasons for this diversion. The first is that we live in an adversarial system. In politics this is expressed by having parties which not only express public disagreement on almost everything, but frequently commit themselves to undoing what their rivals have done. This greatly increases the uncertainty of business, and complicates that long-term planning which is an essential condition for the successful use of science. If, for instance, it were believed that after the next election the Labour Party might command a majority sufficient to allow it to withdraw Britain from the European Community, this would greatly affect the nature and timing of business plans. In industrial relations, matters are very often conducted on the basis of two adversarial "sides," and so as to obscure the common interest of managers and managed in the success of the enterprise. The true interest is that the firm shall have an agreed plan of development, including improvements in technology, which allows it to offer more secure employment and improved wages and conditions. The reality is too often a series of sectional squabbles, among which sensible planning is lost; and an increasing amount of managerial energy is used in avoiding trouble, calming things down, operating complex and burdensome procedures for discussion, and the resolution of disputes between the two "sides." It is, unhappily, relevant to observe that this is not how the Japanese do it.

The other possible reason for the diversion of managerial energy is the weight of government intervention. A quarter of a century ago, Bruce Williams and I concluded that the net effect of government action was favorable to the speedy application of science. I would be less certain of this today. The framework of regulation, taxation, and incentive within which business has to operate has become more complex, while remaining subject to frequent change. Each organization has constantly to be rethinking its adaptation to this framework; and these are not the conditions of simplicity and stability which allow people to turn their minds to the long-run tasks of innovation.

There is a further point about government intervention. Many of the most massive examples have been for the purpose of preventing what would naturally occur in a freely operating economy. Such intervention is not to be condemned out of hand, but its common effect is to enable both managers and workers to avoid unpleasant but necessary decisions. Why face the uncertainties of a new technology and the inconveniences of change if the State stands ready to guarantee markets, or to make up deficits incurred in trying to hold a position with inappropriate products or methods?

Another adverse factor is that profits in both private and public industry are generally too low, and this affects one of the main points of entry of science, namely at the time of replacement of capital equipment. A firm that is not making profits sufficient to keep itself up to date is not well placed to make good the deficiency by borrowing. Profits are low primarily because of a great change in the balance of power between management and workers, associated with an expectation of a higher standard of living which is unrealistic in relation to the increase of the means of providing it. One special danger of the situation is that we have acquired an idea of a normal or reasonable gross profit which is very much less than is really needed if equipment and products are to be kept up to date.

There are problems, too, about human resources. We produce scientists of high quality, but it has been known for many years that they are not supported by enough highly educated technicians. Yet we have continued to give much more attention to degree-level studies of a kind suitable for the training of qualified scientists and technologists than to the development of new institutions and courses that would enhance the numbers and quality of their support staff. We have deficiencies, too, in engineering, which were illuminated by the report of the Finniston Committee (*7*). We do not appear to know how to tackle the extreme conservatism of the educational system and of some of the professions which it serves.

It is possible to go on enumerating general problems which hold back progressive business; but, beyond a point, this becomes a manifestation of our general tendency to denigrate ourselves. For all countries have constraints which inhibit the sensible working of their economies, and which affect their ability to make a successful use of science. Even Japan has industries which are grossly overmanned, and methods which remain old-fashioned because of institutional constraints. Nothing is ever perfect, and it is all too easy for what success exists to be underrated. We might call this the agricultural attitude, remembering George Crabbe's words:

> Our farmers round, well pleased with constant gain,
> Like other farmers, flourish and complain.

Conclusion

We take for granted what our fathers would have thought marvelous; voices and pictures brought in an instant from remote parts of the earth; computers so cheap that they can be treated as toys to play games with; travel which is a hundred times as fast as our legs can provide. There is no doubt of the capacity of science to produce further marvels, but there is doubt about the capacity of human beings to use wisely and well the opportunities provided. The particular problems of the British economy are related to such things as the quality and psychological attitudes both of those who manage our economic affairs and of the public with whom they react. We need, therefore, to think systematically about ways of improving quality and of correcting unhelpful attitudes; but at the end of the day we could do worse than listen to another voice contemporary with the rise of the British Association, that of Samuel Smiles, a great contributor to the theme of the successful use of science:

> Old fallacies as to human progress are constantly turning up. Some call for Caesars, others . . . for Acts of Parliament. . . . A far healthier doctrine to inculcate among the nations would be that of Self-Help.

And again, "National progress is the sum of individual industry, energy, and uprightness, as national decay is of individual idleness, selfishness and vice" (*8*).

References and Notes

1. J. Northcott and P. Rogers, *Microelectronics in Industry: What's Happening in Britain* (Policy Studies Institute, London, 1982).
2. C. Carter and B. Williams, *Industry and Technical Progress* (Oxford Univ. Press, Oxford, 1957).
3. J. M. Keynes, "Memoir of Alfred Marshall," in *Essays in Biography* (Norton, New York, 1963), chapter 14.
4. A. Marshall, *Principles of Economics* (Macmillan, London, 1961), book IV, chapter XIII, paragraph 1.
5. Ned Lud was "a person of weak intellect" who, about the year 1779, in a fit of insane rage, destroyed two stocking frames in a Leicestershire village.
6. *Economic Journal*, March 1962.
7. M. Finniston, chairman, *Report of the Committee of Enquiry into the Engineering Profession* (Her Majesty's Stationery Office, London, 1980).
8. S. Smiles, *Self-Help* (Transatlantic, New York, centenary edition, 1958), pp. 36 and 37.