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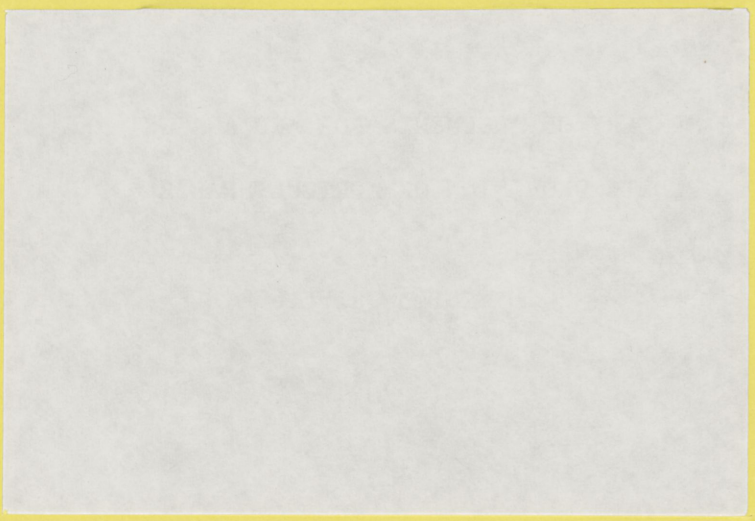
A SUMMARY OF ARGUMENTS FOR AND AGAINST THE PUBLIC PROVISION OF AGRICULTURAL R & D

Colin Thirtle

(WP/02)

Department of Agricultural Economics

Faculty of Economic and Social Studies
University of Manchester
Manchester U.K.



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The first section of this paper borrows arguments from the literature on "the theory of the public interest" to establish the legitimacy of public involvement in R and D in a market capitalist economy. Taking on the burden of proof in this way results in a rather defensive tone. Particularly, the appropriate degree of government involvement becomes a major issue and legislation such as prohibition, regulation, certification or licensing and other measures such as taxes and subsidies tend to be easier to justify than public sector production. Consequently, the arguments against intervention (section two) are followed by a third section that escapes from the often irrelevant and sterile theoretical discussion by examining the arguments for government production taken from the technology policy literature. The final sections try to include a range of issues pertinent to agriculture that are thown up in the earlier discussion.

The basic approach is that of production economics. Thus, if resources are allocated to research, the expectation is that over time there will be a flow of benefits that would not have occurred if the research activity had not taken place. Appropriately discounted, the value of this flow of benefits is the social value of the research expenditure. However, resources used for research are no longer available for other productive activities, the output of which will be reduced. The value of the discounted flow of other benefits lost to society may be viewed as the cost of the research activity. Thus, the allocation of resources to research relative to other activities may be said to be optimal when social value is at a maximum (Nelson, 1959).

Given that in agriculture much new technology is frequently embodied in the intermediate products that are agricultural inputs it is helpful to note that in the abstract arguments below, the product of the research process is viewed as the information itself (the blueprint of the new machine,

rather than the actual machine).

1. ARGUMENTS FOR INTERVENTION BASES ON WELFARE ECONOMICS

(a) On Efficiency Grounds

(i) Inappropriability of returns to investment in research by the private firm is the fundamental cause of market failure. If the marginal value of the information generated by the research process is greater for society, than it is for the private firm, then the profit maximising allocation of resources will not be socially optimal. The competitive market economy will invest less than it should in any case where private profits are less than social benefits.

(ii) Uncertainty of outcome is an essential property of the research process and cannot be insured against. Any risk averse firm will discriminate against investments with a large variance of the profit probability distribution, leading to an allocation of resources to research that is less than socially optimal.

(iii) Indivisibilities or increasing returns in use (Arrow, 1962). In the context of a firm that supplies agricultural inputs and conducts its own research, increasing returns in use simply means that the fixed cost of producing a given innovation can be spread over more units of output by a large firm than by a small one. If increasing returns to scale prevail for any reason, then elements of monopoly power must be expected and all else being equal, monopolists cut output below the perfectly competitive level.

In all three cases,[1] the allocation of resources should be increasingly inadequate, the closer the research is to the basic or pure end of the spectrum, as opposed to the applied end. This is evident since pure research may be defined as "the disinterested pursuit of scientific knowledge without a specific technological objective in view." It follows that public sector support is easier to defend, the more basic the research. However, since

the nature of the market's failure is simply too little resource allocation to R and D, the obvious policy recommendation is subsidies to the R and D industry, rather than public production.

(iv) Preserving Competition Ruttan (1982, p.183) suggests that an "argument that has been made for public-sector research is that it has contributed to the maintenance or enhancement of a competitive structure in the agricultural production, input and marketing sectors. There is, for example, considerable evidence that the flow of new technology from public sector research and development has contributed to competitive behaviour in the seed and fertilizer industries".[2]

(v) Complementarity Another argument raised by Ruttan (1982) is the strong complementarity between public sector investment in agricultural research and education. This again is used to suggest that the market allocation of resources to research may be inadequate.

(vi) Public Goods The effect of new technology on public goods such as the environment and water resources has recently attracted increasing interest as concern over the preservation of rural amenities has drawn attention to the recreational value of the countryside. So long as private firms view environmental resources as a free waste disposal system, there is no incentive to develop technology that economises in the use of these resources.

As different branches of agricultural research become increasingly interdependent, it could be argued that broadly based public sector institutions may have an advantage over private input producers. The AFRC (1985, point 4) notes that "the social function of agricultural research is having an increasing influence on research policy.

(vii) Option Demand Many goods with "public" characteristics may involve a potential willingness to pay that cannot be tapped by private producers (Steiner 1977, p.35). The portion of the welfare impact of such

goods not captured in normal measures such as consumer surplus is labelled "option value". Haveman and Weisbrod (1977, p.155) explain that "this extra value was judged to exist when the individual was uncertain regarding his future demand for an output (because of uncertainty regarding his future tastes and income), when that output had no clear substitutes, and when the future availability of the output was threatened and, if destroyed could not be replaced".

The strongest case for option demand arises in the case of rural amenities (and under-utilised railway lines) in which case public sector intervention may be justified as an extension of the last point, (vi), on public goods. However, a reasonable argument could be made that agricultural research (and even public sector research institutions) have an option value of their own.

(viii) Benefits to Foreign Nationals (and other industries). The AFRC (1985, point 9) has itself argued that, "agricultural research is a valuable and relatively inexpensive form of aid". There is no good reason for ignoring benefits from agricultural research that accrue to foreign nationals. To the extent that the international agricultural research system does succeed in the world-wide adaptation and diffusion of agricultural advances to the benefit of developing countries, these gains should be considerable.

(ix) Unemployed Resources The first three arguments for intervention rested squarely on the standard theory of welfare economics, which assumes that the economy has no idle resources. Efficiency arguments that are the province of the allocation branch of the government are conducted on the assumption that the distribution and stabilisation functions will be performed independently. To anyone with basic Keynesian beliefs, double-digit unemployment provides a further general reason for government intervention.

(x) Discounting the Future The preceeding efficiency arguments are essentially static (allocation in one period). A new range of problems arises with the question of the efficient allocation of goods and services between present and future generations. The effect of risk aversion on investment was covered as point (ii), above, but other considerations remain. In particular, Pigou (1929) argued that the state has a duty to protect the interests of future generations. Since men are mortal they value the satisfactions of the remote future less and thus exhibit a defective "telescopic faculty" leading to socially inefficient intertemporal choice.

(b) Intervention on Distributional Grounds

"Economic science" has attempted to concentrate on efficient allocation, leaving the value judgements associated with distributional problems to be solved independently by lump-sum transfers. Unfortunately, in project appraisal and implementation inter-personal comparisons cannot be avoided. For example, in the case of the development of the mechanical tomato harvester, though the estimated gains to producers were sufficient to compensate the workers for their losses, no compensation was in fact paid. Welfare may not have improved.

(c) Other (Non-Economic) Reasons for Intervention

(i) Social Environment Steiner (1977), in trying to explain the actual pattern of public sector involvement, suggests that some things affect the whole environment of society, by creating broad externalities not linked to any particular good. His examples are the literacy rate, the level of unemployment, the crime rate, the rate of technological progress and the distribution of income and wealth.

(ii) Merit Goods Societies have a tendency towards repressing the supply of heroin and pornography, while subsidising items like the opera, and art galleries. Scientists themselves would certainly have aruged until quite recently that scientific knowledge is good in and of itself and that

any pecuniary spin-offs to the economy are coincidental.

2. THE CASE AGAINST INTERVENTION

(a) The General Case

There is clearly a well defined body of opinion that is opposed to government intervention in the economy as a matter of general principle. Rather than attempting to explain this phenomenon in detail, from the beginnings of laissez-faire to the emergence of the new right, this paper simply identifies some important elements in what has become known as "Chicago economics".

(i) Normative Objections Those who believe, like Simon (1948), that individual liberty is dependent on the preservation of market capitalism, which is threatened by state intervention, oppose government intervention in any form.

Similarly, those with a normative belief in laissez-faire hold "that it is wrong to entrust the control of resources to government officials no matter what social objectives they may be pursuing (faithfully and efficiently)". (Reder, 1982, p.31).

(ii) Positive Objections Reder (1982) defines the Chicago position with respect to positive economics in some detail and claims that it is accepted by virtually all Chicago economists. This position leads to anti-statism by way of a belief in the efficiency of market capitalism, especially as a progressive force, combined with a view that the use of agents always dissipates the gains from the division of labour because they pursue their own self-interest. The state is an agent that is exceptionally difficult to monitor and control and is thus an inefficient means of pursuing any objective.

(iii) Government Failure In reply to Arrow's paper, Demsetz (1969) argued that market failure is a necessary but not a sufficient condition for government intervention. Arrow's "nirvana" approach compares existing

imperfect institutional arrangements with an ideal norm. The appropriate "comparative institutions" approach compares the existing arrangements with an alternative real set of arrangements, raising the possibility that "government failure" may lead to a less efficient outcome than market failure.

(v) Price Distortions Many of the arguments for intervention rest on the proposition that the allocation of resources to research will be inadequate. Implicitly, these arguments assume that all other efficiency conditions for Pareto optimality have been met. However, in agriculture, it could be argued that the initial equilibrium is considerably distorted by the product prices prevailing under the CAP. A wide range of arguments suggest that both the generation and diffusion of new technology will be more rapid at prices that ensure good profits. Thus, rather than being distortionary, market failures in resource allocation to research may be correcting an existing distortion. "Second best" arguments apply to.

(b) Particular Arguments Against Specific Reasons for Intervention

In addition to the blanket objections to government activity listed under 2(a), the major reasons for intervention listed in section (1) have been criticised individually. The more important arguments follow.

(i) Inappropriability Demsetz rejected Arrow's argument on the inappropriability of returns to new knowledge, arguing that appropriability is largely a matter of effective institutional arrangements (patents, particularly) combined with adequate enforcement. The public good character of new knowledge is also dismissed, as arising from an illegitimate "partitioning of economic activity into the act of producing knowledge and the act of disseminating already produced knowledge" (Demsetz 1969).

Interestingly, Demsetz further supports his argument by demonstrating that even if inappropriability does exist, a bargaining solution between producers and consumers will solve the problem. This proposition, called

the Coase theorem, is very much in keeping with the Chicago position discussed above.

(ii) Uncertainty Implicit in the case for intervention in cases of risky investment is the proposition that risk is "socially irrelevant". This has been contested by Hirshleifer and Shapiro (1977) on the grounds that if the theoretical arguments are carried over to using lower discount rates for government projects, the result is an "optimistic bias" that is not called for. Government projects are as prone to failure as private ones. Even if there is a case for a social discount rate that is lower than the private rate, an attempt to cure the distortion between the present and the future by these means will generate a distortion between the public and private sectors. The government sector will be artificially inflated at the expense of private substitutes (more coal and less oil). In British agriculture, forestry has attracted attention on these grounds. The market position has been presented by Miller (1981).

(iii) Indivisibilities The basic case against nationalisation or regulation of monopoly is that stated originally by Friedman (1962). Monopoly is transitory and relatively unimportant but becomes institutionalised, permanent and more of a problem with public sector involvement. Hence it is best left alone.

(iv) Other Arguments The arguments against the other specific reasons for intervention can be dismissed quickly as they are well known and not very subtle. For instance, Keynesian notions of governmental responsibility for ensuring an adequate level of economic activity have given way to the vertical long run Philips curve and the natural rate of unemployment. Intervention on distributional grounds has been generally opposed as detrimental to efficiency. Lastly, arguments for agricultural research as foreign aid are open to attack by the "case against aid" lobby on the one hand and those who distrust "development from above" on the other.

3. BROADER ARGUMENTS FROM THE TECHNOLOGY POLICY LITERATURE

Theoretical welfare economics formed the basis of the arguments for government intervention listed in the first section. This body of theory is static in its approach and rests on the proposition that perfect competition leads to Pareto optimal resource allocation. Given that innovation is clearly a dynamic process and is incompatible with perfect competition[3] it is surprising that the approach succeeds.

Yet to a considerable extent it does. The largely non-theoretical technology policy literature has assimilated the arguments from welfare economics. Frequently, the first three propositions (inappropriability, uncertainty and indivisibility) play an introductory role in policy papers on government's role in innovation (Holloman, 1979, p.293, for example). Some authors discuss the empirical evidence on the divergence between social and private rates of return with apparent approval (Horwitz, 1978, pp.268-9) whilst others are more sceptical (Shonfield, 1981, pp.8-10). All the other arguments listed in section (1) appear in the discussions of technology policy (with the possible exception of option demand) but the emphasis is usually on preserving competition (or promoting rivalry; Hill and Utterback, 1979, p.322), public goods (Shonfield, 1981) and improving the environment (technological infra-structure) in which firms innovate (Rothwell, 1984).

However, whereas the micro-based literature of welfare economics discusses hypothetical allocative efficiency the technology policy literature pays lip service to theory before going on to stress the macro approach of economic goals and the role that innovation can play in achieving them. Quite typically Freeman (1982, p.220) argues that "The promotion of major new technological systems and of productivity growth based on technical change may be an important means to help restore the economic health of the mature industrialised countries". Thus, the technology policy literature may be viewed as spelling out argument (ix), which raised the macro issue of

unemployed resources. However, the dynamic concepts of technology policy are a far cry from the static demand management approach of Keynesian economics, which was the emphasis of point (ix).

Indeed, Freeman is modest relative to others who promote innovation as a universal panacea. Hill and Utterback (1979, p.318) begin summarising their finding with the assertion that new technology "can also help control inflation, create jobs, enhance productivity, maintain growth, enhance environmental quality and support a healthy balance of trade with other nations".

Though the claims of most authors are a little more modest, many argue that innovation is crucial to future international competitiveness, growth rates and employment, which is enough to make government involvement inevitable since government "accepts responsibility at least in part for education, defence, health, the environment, energy and growth". (White, 1981, p.160).[4]

To explain the arguments for government intervention raised by the technology policy literature it is necessary to briefly consider the ideas that have been pursued in this area. Following Schumpeter (1947, 1961)[5], the literature stresses the autonomous nature of invention and the tendency for innovations to appear in clusters, giving rise to long waves in economic activity. These Kondratiev cycles (Rothwell and Zegveld, 1985, pp.29-30 map out the history) thus are part of the exogenous, or technology push, side of innovation that tends to be associated with basic science, radical new major technologies and the early stages of the growth of new industries. Thus a technological regime is a framework of knowledge, describable in terms of a set of basic design parameters, which guides and constrains engineers and innovators in the design of a range of products and their related processes of production. This knowledge is shared by all firms in a given technological area. A design configuration, by contrast, relates to specific products and processes and is to be identified and mapped in terms of the performance characteristics, inputs coefficients and product attributes, which embody a

particular constellation of the basic design parameters." (Metcalfe, 1985, p.7). The regime provides continuity while the configuration gives variety. Both are elements of technology push which is guided by a set of "user-demand characteristics defining a technological corridor". (p.8)

However, the demand-pull side of the equation becomes stronger once the technological system or paradigm is established.[6] The development of the technological trajectory, the boundaries of which are defined by the nature of the paradigm, (Dosi, 1982) becomes increasingly demand-influenced as the stream of secondary inventions that improve the original major innovation become the dominant factor.[7] These are Hicks' induced innovations, "the children of original innovation" (Hicks, 1977), the product of institutionalized, applied R and D. If the original impulse has caused a rise in wages, these induced innovations will have a labour-saving bias. This is the source of the Hicks-Ahmad model of the factor-saving direction of technical change.

To this background of long waves in economic activity, powered by clusters of radical new innovations that constitute the new paradigm (regime, system?) must be added the technology gap explanations of international trade that became widespread in the 1970s. These theories, combined with the advent of competition from the developing countries, encouraged the view that to remain competitive, industrialised countries must ensure that they produce high technology products (White, 1981, p.157). Similarly, having argued that "technological innovation is the dominant form of competition in the manufactured goods sector", Metcalfe and Soete (1984) conclude "that the development of new technology cannot realistically be treated in a closed economy context".

Thus both growth and comparative advantage depend on being at the fore-front of the emerging radical technologies that will be the foundation of the next upswing of the long cycle. The government must devise policies to ensure this result simply because "the unaided market mechanism is not enough"

(Freeman, 1982, p.220). Government involvement has increased with growing belief on the part of governments[8] that one means "of breaking out of the current recessionary cycle is the stimulation of technological innovation in industry." (Rothwell and Zegveld, 1985, p.83).[9]

Against this background, the recent drift of government innovation policy is understandable. Whereas, "the first de facto science policy institutions in many countries were government nuclear research organisations" (Freeman, 1982, p.195) and government R and D policy was dominated by support of military R and D to be embodied in weapon systems procured by the government, even the U.S. and Britain now show a keen interest in new civil technology. The areas of interest are indicated by Ashworth's (1984, p.35) list of recent government publications. Topics included semiconductors, robots, computer aided design, biotechnology and information technology.[10] The point is made by Stout (1981, p.119) who says "put the micro-processor in the first rank of Schumpeterian long waves. Yet other major developments of technique are clearly overlapping and combining with it - lasers, fibre optics and biotechnology are almost equally 'generic' and rich in potential applications". At the other extreme, this emphasis on structural change and emergent industries puts agriculture at the other end of the scale. It is the archtypical declining industry[11] with a rapidly falling share of output and employment (see the diagram provided by Freeman, 1982, p.6).

These propositions are not the product of theoretical reasoning. Rather they result from empirical investigations, often case studies that can approach the problem either by considering how the innovation process works and hence how the government may improve it, or by inter-industry or international comparisons of the outcomes arising from what governments actually have done or not done (Holloman, 1979, p.293). The type of policy recommendations derived vary considerably but Hill and Utterbach's (1979) volume is not atypical. Contributors suggest that government should concentrate on supporting

basic research in areas with potential, concentrating on the early stages of development and risky innovations. Competition should be promoted, as should close links with users and diversity should be the rule even at the cost of duplication.

Whilst these propositions do not differ from the conclusions that are reached by applying microeconomic theory,[12] other authors have (perhaps unwittingly) emphasised issues that were excluded from the theoretical discussion either by its assumptions or its static nature. Thus White (1981) stresses the role of government in designing institutional arrangements (and creating institutions) to ensure rapid and efficient information flows. "The objective is to organise a market for technologies" (White, 1981, p.162). Similarly, Stout (1981, p.118) emphasises the fact that even the existance of a functioning market mechanism is not sufficient. The speed of responses is crucial to success. This same conclusion is reached by Shonfield (1981, p,18). "The assertion of a public interest, either through state research establishments or by means of conditions attached to the provision of finance to private researchers, helps to ensure that the diffusion of useful results is delayed less than it would be in conditions of pure private enterprise by the (legitimate) demand of the innovator to appropriate some measure of monopoly profit". In the next section, this line of reasoning is used to provide a justification for public production.

4. PRIVATE, COLLECTIVE AND PUBLIC R & D

The basic arguments for intervention perform reasonably well in establishing grounds for public support but don't really explain the extent of public sector production in R and D. Nelson (1982, p.2) acknowledges reluctantly "that the general theoretical analyses and empirical observations of economists provide only limited and incomplete guidance."

The historical evidence suggests that much research activity has always been conducted outside the narrow confines of profit maximising firms. Viscount Townsend of Rainham and Thomas Jefferson would not have cared about appropriability (even if they had understood the concept). Since the problems became too great for rich individuals, there is considerable historical evidence of collective action in the field of R & D. Allen (1983) has coined the term "collective invention".

The clearest case for public production is provided by Nelson (1982) who has resorted to careful interpretation of case studies to compensate for the lack of theoretical guidance.[13] His basic conclusion is that market failure in R & D is not a matter of too few resources, but the inability of the market to spawn the appropriate portfolio of projects. Two reasons are offered. Firstly, patent protection or industrial secrecy lead to duplication or near duplication of R and D efforts. Discovering that which is already known or devoting resources to product differentiation for its own sake has little social value.

Secondly, "major theoretical uncertainties call for a variety of approaches with open knowledge of routes being explored and what is being found along the way, and not for a big push along one particular road". (p.480).

Nelson also conjectures that in industries where there was government (particularly university) involvement in basic research, information exchange was wider and deeper and technological advance faster. Particularly the

treatment of research results as public property is contagious, being quickly caught by the private sector researchers in the industry.

On the basis of Evenson's paper on the agricultural sector, Nelson concludes that the government in effect defined certain areas, where information flows were particularly important, to be nonproprietary and proceeded to fund research in these areas. In applied research a reasonably well-defined division of labour between publically and privately funded research has also emerged.

5. FURTHER ISSUES

(a) Differences Between Mechanical, Biological and Chemical Research

In agriculture most private R and D is carried out by the companies that supply fertilizers and other chemicals, by the seed companies and by the farm machinery and equipment companies. The case for government intervention, based on the issues covered in section (1), varies considerably for different types of research:

(i) Mechanical Research On the basis of a wide-ranging recent research project, Binswanger (1984, p.32) concludes that "on a world-wide basis, public sector research has contributed little to machinery development". He argues that this is so because gains from innovative effort are largely captured by the sale of machines.

(ii) Biological research is quite different. Binswanger (1984) regards public funding to be crucial. Evenson (1982, p.274) suggests that a natural division of labour has emerged with the public sector producing plant breeding material while the private sector develops the final product.[14]

(iii) Chemical Technology Ruttan argues that three types of research intervention are necessary:

1. Modified regulatory procedures to ensure that the private sector develops chemical and biological agents compatible with the two goals of output and amenity.

2. Expanded support for public sector institutions developing biological and cultural control agents and procedures i.e. on the biology of insect predatorsand host populations, identification of insect control agents, the design of control technologies, the breeding of insect resistant crop varieties and the design of cultural practices to depress insect populations.

3. Public sector support for the design and operation of insect population management programmes. Here the roles of the public and private sector are particularly ill-defined.

(b) Returns to Agricultural Research

Though Nelson's conclusion that it is not too little or too much that is the market's failure in R and D, but the wrong portfolio of projects,appears plausible, interest in calculating the social internal rate of return for projects will probably continue. A high rate of return can be interpreted as empirical evidence of market failure (under-investment in agricultural research).

The collected results of many studies are presented in Ruttan (1982, pp. 242-3) and in Evenson (1982, pp. 262-3) who divides them into two classes. Those classified as "imputation studies" rely on cost benefit methods to measure and compare costs and benefits. Studies of this type have been criticised by Wise (1984). The alternatives are statistical estimates derived from regression analysis. Statistical studies have the clear advantage that the data can reject the hypothesis that research is productive and the reader has statistical information by which to judge the results. By comparison, there is little basis for judging the reliability of imputation studies. The vast majority of these studies show high internal rates of return.

6. CONCLUSION

The Importance of Institutional Change

Ruttan (1982) concludes his discussion of the public and private

sectors in R and D by observing that the agricultural system is becoming increasingly complex and interdependent. A multidisciplinary approach to the entire system, combining integrated mechanical, biological and chemical research is required. Both the public and private sectors should play major roles and appropriate institutional innovation is required to provide effective patterns of communication and collaboration.

NOTES

1. Though the issue does not appear to have been raised in the literature, inappropriability, uncertainty and monopoly are inter-dependent. Appropriability is greater for larger firms and monopolies, which also suffer less from uncertainty, being able to pool many research projects to reduce risk. Thus inappropriability and uncertainty both tend to generate monopoly and are reduced (but not eliminated) in the process. This relationship lies behind Schumpeter's hypotheses on the innovational advantages of large firms and monopolies (listed in Kamien and Schwartz (1982, p.47).

2. Freely available public sector research output overcomes the "increasing returns in use" problem and does constitute a genuine argument for public production.

3. This was clear to Schumpeter, as the quote in Shonfield (1981, p.6) shows and has been formally stated by Nordhaus (1967).

4. Historically, defence has dominated the government budget in both Britain and the US, though the share of civil technology spending has been rising. In the US case the civil departments with the largest federal technology budgets are Energy and Health, Education and Welfare (of which health is the dominant partner). The National Science Foundation, which has primary responsibility for basic research in the sciences is a distant third (Horwitz, 1979, p. 261).

5. Freeman (1982, pp.211-214) explains the difference between the two models of technological change that appears in Schumpeter's works.

6. Freeman (1982, p. 211) argues that "exogenous science and new technology tend to dominate in the early stages, whilst demand tends to take over as the industry becomes established". This presumption that market forces come to be dominant in time (that demand pull replaces technology push and that private will replace public) is clear too in Yoxen's (1984) analysis of biotechnology. He argues that building a research base in the "medium term" encompasses a period of about 20 years. "Consequently the recommendations are organised so as to activate mechanisms of "technology push" with a switch to "market pull" when demand has been established". (p.215).

7. "Exogenous science and new technology tend to dominate in the early stages, whilst demand tends to take over as the industry becomes established". (Freeman, 1982, p.211). Freeman also suggests (p.214) that in the early stages of autonomous innovation and the long wave cyclical upswings that it generates, small firms play an important role. As the industry matures, so large firms come to be dominant.

8. Wallard (1984, pp.193-4) gives six reasons for the Department of Industries' involvement in innovation. These are 1) because industry under-invests in R and D, 2) to stimulate product innovation and hence trade performance, 3) to accelerate innovation in firms, 4) increase cooperation between firms, 5) stimulate "new" technology and 6) increase spin-off and transfer of technology arising from R and D conducted to meet government's own needs.

9. Rothwell (1984) divides innovation policies into those that affect supply, demand - side tools and policies affecting the environment in which innovation occurs. His alarming list of policy tools (p.150) has twelve categories.

10. The Alvey Programme for advanced information technology provides a good example of recent policy. It will cost £350 million over five years, of which the government is paying two-thirds. (Rothwell and Zegveld, 1985, p.265).

11. This could change if biotechnology advances to the point where sugar and cereals can be used to produce substitutes for the products of the petro-chemical industry.

12. To an extent the conclusions reached may simply reflect the fact that researchers tend to discover what they were expecting to find.

13. Nelson's results are in contrast to the old economic theories of R and D which suggest under-investment. Though Nelson does not mention the new theories of R and D, they do in fact reach the same kind of conclusions. Hirschleifer and Riley (1979, pp.1043-46) provide a survey of these developments, in which the possibility of over-investment is raised. The problem is that of a fugitive resource or common property rights. Just as over-fishing occurs because nobody has property rights over the fishing grounds, so too in R and D, nobody is auctioning off the right to search for a new idea.

14. The ongoing controversy over "plant breeders' rights" demonstrates that the actual difficulties involved in arranging appropriate patenting arrangements are very clear in seed production. More than twenty countries have passed legislation to enact PBR, which should increase the appropriability of returns and hence encourage private sector research.

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