SUSTAINABLE AGRICULTURAL DEVELOPMENT: THE ROLE OF INTERNATIONAL COOPERATION

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The Role of the Private and Public Sectors in the Development and Diffusion of Biotechnology in Agriculture[1]

The dividing lines between public and private knowledge in the evolution of a technology is a topic to which economists have given little attention. (Nelson, 1982)

INTRODUCTION

Much ado has been made about the revolutionary nature of the so-called new biotechnologies. For instance, the OECD (1988) argued that 'in the agricultural sector, biotechnology clearly represents a means for pivotal change'. Similarly, Lacy and Busch (1989) state: 'In the past ten years dramatic new developments in the ability to select and manipulate genetic material have generated a new basic science frontier in the public research sector and ignited unprecedented interest in the industrial use of living organisms.'

In this paper I want to suggest that the forthcoming biotechnology revolution is not just the product of a scientific watershed flowing from the discovery of the double helix, but also the culmination of a more gradual evolutionary process over the past century involving revision of intellectual property rights to biological research. While some of the key issues from a scientific perspective hinge on improved knowledge of basic life processes and the potential of the consequential new biotechnologies to overwhelm technical constraints on increased production, the question of intellectual property rights is much more significant for the topic of this paper. Not only is the delineation of these property rights an important determinant of the respective roles of the public and private sectors in agricultural biotechnology research, but arguably it is the single most important policy instrument available to governments to influence the extent to which one sector substitutes for the other.

However, this is not the only significant policy issue, and the following questions are indicative of some of the issues of relevance to the respective roles of public and private sector R&D in the development and diffusion of agricultural biotechnologies. First, was the recent extension of intellectual property rights to allow new knowledge embodied in life forms to be patented in the public interest? If so, is there still a role for public sector research to complement that taken over by the private sector? Finally, are there remaining

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forms of market failure not addressed either by extended intellectual property rights or by complementary public sector research, and do any such distortions justify government regulation of private sector R&D? Owing to space limitations, I plan to touch only on the second and third issues, in order to focus on the first.

Because of the perspective taken in this paper, no attempt will be made to use the term 'biotechnology' in a precise manner. In the literature, it is possible to find different definitions of biotechnology, ranging from the quite specific to the very general. According to Persley (1990b), biotechnology includes both 'traditional biotechnology' and 'modern biotechnology'. The latter encompasses technologies based on use of recombinant DNA technology, monoclonal antibodies (MCA) and new cell and tissue culture techniques. Of these modern forms of biotechnology, it is recombinant DNA (rDNA), or genetic engineering as it is popularly known, that has aroused the greatest public interest because of the prospects of transgenic organisms, as well as the greatest controversy because of the alleged risk of environmental problems. For these reasons, and because genetic engineering is the form of biotechnology research which brings the issues into sharpest focus, this paper has been written mainly with this particular form of modern biotechnology in mind. However, the essential theme is that the role of public and private sector research in biotechnology development and diffusion merely epitomizes the issues for a broader class of patentable self-reproducing innovations.

To provide background for these issues, the next section presents a fairly brief overview of the findings of several recent studies of the relative roles of public and private sector agricultural biotechnology R&D, and of how they have evolved over the past decade or two. These findings are then placed in historical perspective relative to the rather longer time-span of the history of agricultural R&D in general. In the third section, normative considerations are introduced in a review of the efficiency losses generally associated with publicly funded research on the one hand and patent protected invention on the other. This is followed by a discussion of the special characteristics of biotechnologies likely to influence the magnitude of these efficiency losses, or otherwise to provide grounds for a role for the government sector to substitute for private sector R&D. Other considerations pertinent to a role for the public sector to complement or guide private sector R&D are briefly discussed in the final section.

THE EVOLUTION OF AGRICULTURAL BIOTECHNOLOGY R&D

The eventual impact of biotechnology R&D on the roles of the public and private sectors in agricultural R&D is yet to be determined, but trends to date indicate that the combined effect of the development of rDNA technology in combination with recent legal decisions establishing property rights in biological organisms will further shift the division of labour in agricultural R&D away from the public sector institutions and toward private industry. Comprehensive evidence on the extent of involvement of private industry in agricultural rDNA technology development comes from the United States, where private industry has also been investing heavily in public sector agricultural research. For instance, Lacy and Busch (1989) found that agribusiness contributed an estimated $40 million to university bio-engineering research in 1983, and that the amount spent by biotechnology companies in grants and contracts to universities trebled in the following year: 'This funding represented approximately 16–24% of the public sector universities' total funds expended for biotechnology in 1983 and 1984 compared to an average of 3–5% that industry provides for all research funds expended in institutions of higher education.'

At least in the USA, such statistics under-state the importance of private sector research because they do not include in-house research. For instance, new biotechnology firms which were started almost exclusively to commercialize innovations in biotechnology, and which spend a considerable proportion of their funds on development, if not pure research, were estimated to have raised about $450 million in a five-month period in 1983. Lacy and Busch (1989) note: 'A 1985 survey of the agriculture biotechnology firms indicated that they employed more than a thousand molecular biologists and invested over $200 million in agricultural biotechnology research and development in 1984.' There is now some evidence emerging that the relatively small but entrepreneurial start-up biotechnology firms which were so prominent during the early stages of the industry will be swallowed up, or at least supplanted in importance by in-house research conducted by established companies in the agribusiness industry.

Persley (1990b) presents more recently available global information on the relative importance of public *vis à vis* private sector funding of biotechnology research which is summarized in Table 1.

TABLE 1 *World-wide R&D expenditure on biotechnology (1985 estimates, in US$m)*

Type of biotechnology	Seeds	Agricultural Microbiology	All	Other	Total
Private	350	200	550	2 150	2 700
Public	250	100	350	950	1 300
TOTAL	600	300	900	3 100	4 000

A persuasive case can be made that the history of agricultural R&D has involved a gradual transfer from public sector institutions to private industry, and that the recent outburst of private sector investment in biotechnology merely represents the continuation of a trend that has been going on for at least a century, if not longer. Lacy and Busch (1989) suggest that this trend towards industrialization started in the food-processing sector with the development in 1785 of the first fully automated continuous process flour mill.

This was followed in 1789 by the introduction of bread-kneading machines in Genoa. Hog slaughtering was partially automated in 1830, and pasteurization of dairy products in the late nineteenth century marked a further step forward before full industrialization of poultry production in the twentieth century. The rise of the farm equipment industry followed closely behind the development of processing, with the introduction of stationary steam engines on US farms in the early 1830s, and of tractors for cultivation by the turn of the century. By the first part of this century, the role of private firms in agricultural R&D was 'confined largely to the manufacture of farm machinery and the processing of farm products', but, after the Second World War, the private sector also became heavily involved in chemical R&D.

The transition from public sector to private sector R&D started rather later for plant-breeding research. Lacy and Busch (1989) state:

> Until 1923, USDA regularly distributed free seed, collected from around the world, to farmers who wanted to test the seeds on US soils. As the techniques and effectiveness of plant breeding improved, USDA discontinued the distribution of free seeds. Instead, the state agricultural experiment stations (SAES) began to disseminate new varieties developed by their breeders to seed companies who multiplied and sold the new varieties to farmers. The development of hybrid corn shifted the division of labour again. Experiment stations gradually shifted to the development of parent material and significantly reduced the production of finished products for hybrid crops. With the growth of the seed development (as opposed to multiplication) industry, came increased presssure on the public sector to cease producing finished varieties.

This tendency for the private sector to move into a research area once intellectual property rights have been established, and then to crowd out public sector R&D, may well continue in the field of biotechnology. Lacy and Busch claim that the recent development of private biotechnology research capacity has resulted in 'pressure on public sector scientists from industry to abandon varietal breeding, pressure from administrators for greater productivity'. In addition, the lure of large amounts of private money for biotechnology research has led to a change in disciplines in the SAES, although the authors also quote survey results indicating that the experiment stations have been hiring large numbers of molecular biologists, and that many of the positions were obtained by reducing the scope of conventional breeding programmes.

PUBLIC VERSUS PRIVATE SECTOR R&D – A CONCEPTUAL FRAMEWORK

What considerations need to be taken into account in evaluating whether a particular area of inventive activity should be conducted by private or public sector R&D organizations when it is feasible for the state to establish intellectual property rights? One way of approaching this issue is to treat it as synonymous with the question of whether patent legislation should or should not cover the particular class of inventions under consideration.[2]

It is commonly accepted that the potential for market failure inherent in the public good characteristics of knowledge produced by research provides both the justification and guidance for governmental intervention in the market for inventive activity. Of the two most widely employed forms of government intervention, one has been directly to fund and organize R&D activity in public sector institutions, and the other has been to confront the appropriability problem by establishing legal protection in the form of patents for the intellectual property rights of the inventor. In much of this paper, these two alternatives will be treated as polar stereotypes of public and private sector R&D, respectively.

In a world of perfect knowledge, allocative losses associated with public sector R&D would be limited to the excess burden associated with raising the revenue to fund the research. In a world of imperfect information, public sector R&D is likely to incur additional welfare losses due to misallocation of research resources in aggregate and/or between alternative areas for investigation. The wealth of evidence on high rates of return to public sector agricultural R&D is often cited as *prima facie* evidence of under-investment by governments in research.[3] Conversely, in the private sector, the race to discover and patent new technology is the more likely to result in over-investment in research. This is the so-called common pool problem, in which individual inventors ignore the marginal effect of their research activity on aggregate research productivity. Unless the conditions of the patent are optimized in some way, such behaviour will lead to over-investment in research and associated allocative losses because the expected average benefit to a competitive R&D firm from successfully developing and patenting an invention will exceed the expected marginal social product. In addition, the resulting technology will be under-utilized if patent holders attempt to appropriate the benefits. This widely recognized deadweight loss associated with the patent system arises because potential adopters are charged for knowledge which is nonrival in use. Less widely recognized is the likelihood that the patent system will retard the rate of innovation diffusion because appropriation of research benefits by inventors will reduce innovation profitability to potential adopters.

Wright (1983) has shown that any potential advantage of patents over publicly funded contract research lies in informational asymmetries between public funding agencies and private profit-maximizing firms with regard to market opportunities, the cost of research and its probability of success. This conclusion is supported by the findings from an analytical model in which the choice of the superior alternative took account of the following three allocative difficulties: lack of appropriability of knowledge, deadweight loss of the patent, and the common pool problem. As Wright acknowledges, there are other considerations besides those discussed above that are relevant to the choice between public and private sector R&D. Of the other allocative difficulties, the most important stems from the joint product nature of research output. As Nelson (1987) puts it, there are two different aspects of technology, one being operative knowledge,[4] which can be embodied in patentable inventions or 'techniques', and the other being the so-called 'logy' or body of generic knowledge about the way technologies work. The public good dimension of basic research[5] has been part of conventional wisdom for many years, but Nelson (1982, 1987) has gone further and argued that even applied R&D adds to the stock of knowledge about where and how to search for new technologies. Empirical support for such an externality is provided by Jaffe (1986) who found that R&D productivity is increased by the R&D of 'technological neighbours,' and that firms adjust the technological composition of their R&D in response to technological opportunity.[6]

Because this 'logy' has strong public good properties, including being non-rival in use as well as reducing the costs and/or returns of subsequent research, it is neither possible nor desirable for the private sector to capture all of the benefits from this component of research output, even if 'ideal' patents could be designed. However, while such knowledge has the potential to enhance future research productivity, this potential will only be realized to the extent that it is freely available as an input into further research by all parts of the R&D industry. In particular, if the establishment of intellectual property rights to biotechnologies adversely affects this positive information externality, then the short-run stimulus to private investment in R&D provided by patents may be offset in the long-run by declining research productivity. This aspect may well emerge as the key issue in any evaluation of the respective roles of the public and private sectors in biotechnology R&D.

Proponents of the patent system argue that the requirement to disclose the scientific basis of the innovation as part of the patenting process makes sure that this information externality is not lost. However, there are some counter-arguments. In particular, there is no incentive under the patenting system for commercial R&D firms to disclose any of the results of research projects which do not generate a patentable innovation/invention. Thus the pool of knowledge put into the public domain as a result of the patenting requirement for disclosure is only a small fraction of the information generated by commercial R&D firms. The other point to note is that, even in the case of patentable inventions, the disclosure requirement only achieves partial release of relevant information. Furthermore, even if no attempt is made to keep the 'logy' secret, the much higher search costs faced by other firms seeking to discover such private information (compared to the more traditional scientific approach of publication in journals or in public conferences) will seriously reduce the extent of the informational externality. The finding by Scotchmer and Green (1990) that the 'stringency of the novelty requirement in patent law affects the pace of innovation because it affects the amount of technical information that is disclosed among firms' tends to support this argument.

Unfortunately, virtually nothing is known about the size of the potential allocative losses identified above as relevant to the choice between public and private sector R&D for any area of agricultural research, let alone one as novel as biotechnology. Clearly, institutional arrangements specific to the country involved will be critical determinants of these losses. However, even for a simple choice between the two highly over-simplified and stylized systems outlined above, there is an almost total dearth of empirical information about the nature or magnitude of the trade-offs between the various potential losses. In the next section, some of the characteristics peculiar to biotechnologies which might influence the size of these allocative losses or otherwise be relevant to the role for public sector R&D are discussed in qualitative terms.

CHARACTERISTICS OF THE EMERGING BIOTECHNOLOGIES

Biotechnology research is distinguished from other more conventional forms of agricultural research by a number of characteristics, only some of which are relevant to the optimal mix of public versus private sector participation in the development and diffusion process. The most commonly commented on is the revolutionary nature of the scientific basis for molecular biology. In terms of Evenson and Kislev's (1976) stochastic model of applied research, the significance of this property is that it implies that the expected rate of return to applied rDNA research is likely to be much higher in the foreseeable future than from more conventional types of agricultural research which, arguably, are suffering from *technological exhaustion.*[7] Given that biotechnology research is likely to follow a similar productivity cycle to other areas,[8] and will eventually become less profitable than is apparently the case at present, determination of the optimal level of investment in R&D is an optimal control problem which is too difficult to solve, given current knowledge. However, if, as seems likely, this optimal level of aggregate investment varies over time, then the evident greater flexibility of the private sector to adjust its investment in research is an advantage.

It has already been suggested above that biotechnologies belong to a subset of biogenetic inventions which are both embodied and patentable, and that, within this class, their only distinguishing characteristic is novelty. Conversely, as Stallman and Schmid (1987) point out, what distinguishes most biotechnologies, and rDNA technology in particular, from other embodied and patentable technologies is that they are embodied in a living organism with the intrinsic capacity for self-replication.[9] This unique property has crucial implications, both for the ability of the private sector to appropriate the benefits from its research, and for the utility of the disclosure provisions in patenting provisions as a device to offset the information externality described above.

Owing to this innate capacity for self-reproduction, the cost of imitation of biotechnologies is negligible, and less likely to be subject to economies of size than for mechanical, electrical or chemical inventions. Equally important, potential imitators have no need for access to the 'information' component of the invention[10] in order to reproduce it, so lack of knowledge is no impediment to the ability to free-ride. Consequently, the detection of imitations and enforcement of any property rights conferred by the legal system are much more difficult and costly. By the same token, this same characteristic reduces the cost of innovation adoption, and thereby speeds up the rate of diffusion of the technology and reduces any deadweight loss from under-utilization of knowledge.

Schmid (1985) notes that 'Because of high information costs, patent laws for plants and micro-organisms cannot provide exclusivity of use without eliminating original and non-copied substitutes.' The impotence of computer companies to counter software piracy provides a graphic example of the possible dimensions of this problem. After reviewing experience on the operation of the 1930 Plant Patent Act, which permits asexually propagated plants to be patented, Stallman and Schmid (1987) found that 'plant patents in fruits and variety protection in field crops have not alone given the protection and exclusivity necessary to allow market returns to cover research costs.' They further concluded that, owing to differences between biology and chemistry, patent protection for biogenetic inventions is unlikely to allow biological researchers successfully to appropriate benefits in the manner achieved for chemical inventions. If this prediction proves to be accurate, there may still be a case for public sector funding of applied biotechnology research simply to ensure a high enough level of aggregate investment.

This reproductive capacity of rDNA technology is also relevant to the debate about the impact of patents *vis-à-vis* public funding on the possible under-utilization of the 'logy' component of research output. Since the disclosure provision of patents is less effective for such innovations than for other classes of inventions where the cost of imitation is a function, *inter alia*, of knowledge about the way to reproduce the technology, private R&D firms may try to keep as much as possble of this type of knowledge secret, thereby exacerbating the information externality. There is much anecdotal evidence relating to biotechnology at the current stage of development which suggests that there are considerable and very significant restrictions on the dissemination of information between scientists in competing firms, and that the contractual relationships which these firms form with public sector scientists extend these constraints to public sector R&D as well. On the other hand, Nelson (1987) argues that the private sector has a vested interest in keeping the 'logy' of its science in the public domain, and in other areas has developed a variety of mechanisms (which he documents at some length) to ensure efficient utilization of such knowledge.

The discussion above presumes a traditionally organized public research sector, which is funded mainly or totally from government revenues, and which publishes research results without attempting to exploit commercially any new technologies developed as part of the research programme. In some countries at least there has been a trend away from this 'pure' model during the past couple of decades. For instance, in Australia, government funding is gradually being displaced by industry funding (financed partly by production levies) to the point where the wool industry research funds are now providing the majority of funding (some 58%) in the Division of Wool Technology and over one-third of the funding (36%) in the 'Division of Animal Production' in CSIRO, which is the major public scientific research organisation in Australia. Public research organizations, including universities, are also attempting to market commercially valuable technologies developed from their research programmes. In part this is simply a response to cut-backs in government funding, in part it reflects altered opportunities brought about by changes to the law regarding intellectual property rights, and in part it is a response to pressure from industry funding bodies to appropriate the returns from technologies generated by 'their' research programmes.

Clearly this trend towards commercialization of public sector research diminishes the differences between public and private sector research. James and Persley (1990, p.372) suggest that industry will have a comparative advantage in these circumstances because of superior access to capital markets, more diverse organizational form, better ability to consolidate a critical mass of scientific resources within a core research group to capitalize on complementarities between agricultural and medical biotechnology, greater marketing expertise, and access to global markets and associated economies of scale. As a result, they predict that the private sector will emerge as the predominant provider of agricultural biotechnologies. Such a trend would be of concern if it increased the likelihood of the public sector being crowded out by the private sector, and especially so if there are unfavourable externalities or distributional consequences from the use of biotechnologies.

Another concern if the possibility that industry will distort the direction of public sector research rather than crowding it out. One of the features of the biotechnology industry has been the forging of such extensive public/private sector links that it has been described as the new university–industrial complex. It is outside the scope of this paper to discuss possible advantages as well as problems which could flow from this association, but it is already the subject of an extensive literature.[11] In terms of the topic of this paper, it is worth noting that many of the researchers involved in the emerging alliance between public sector basic science and private sector technology development do not belong to traditional agricultural research establishments. A key question is whether they will prove to be a complement to , or a substitute for, existing publicly supported agricultural research, or merely a vehicle for cross-subsidization or private R&D.

OTHER POLICY ISSUES FOR PUBLIC SECTOR BIOTECHNOLOGY RESEARCH

A number of authors have argued that the greatest benefits from genetic engineering are likely to be found in Third World agriculture, while the greatest propensity to pay for its technologies are to be found in the developed world. The contribution that biotechnology could make to agricultural productivity and increased food production has been documented in Persley (1990a). Barker (1990) has suggested that the potential to continue increasing food production without biotechnology is limited, since yield plateaux have been reached for several major food crops, and because the opportunities to expand the area under cultivation are almost exhausted. If the biotechnology revolution were to by-pass developing countries, the distributional consequences would be disastrous, but to date private sector R&D has been concentrated almost exclusively in the industrialized countries.

There are two other potential characteristics of biotechnologies which do not seem to have been widely recognized and which, if they materialize, could have important implications for government policy towards rDNA research. The first relates to the capacity of rDNA technologies to break free of, or at least diminish the importance of, environmental constraints on the production of food and other agricultural products. For instance, the OECD (1988, p.27) predicts that the ‘effects will be felt in an increasing convergence of agriculture and industrial practice.' If this hypothesis proves to be correct, then biotechnology-based supply curves will be more elastic than the equivalent supply from conventional agriculture, which could result in major distributional effects. For instance, if this led to a marked reduction in the real price of food, then, as Pinstrup-Andersen *et al.* (1976) have pointed out, the distributive implications would be strongly progressive, as well as helping to alleviate malnourishment. A related but separate consideration is the capacity of biotechnology to stabilize production variability and, at least in that limited sense, to make agricultural production more comparable to industrial production.

These possibilities suggest that the potential exists for public sector research to play a complementary rather than competitive role to private sector research. However, there are concerns that international differences in protection afforded by the legal system to intellectual property rights, as well as in the cost of imitation, will adversely influence the respective roles of private and public R&D on biotechnology for agriculture on the world scene. Evenson and Putman (1990) clearly demonstrate that, while products of biotechnology R&D are afforded significant patent protection in the USA, and to a similar extent in a number of other industrialized countries, the situation in the developing world is very different, with the legal systems of most countries affording very little protection to all forms of agricultural inventions, but in particular to technology embodied in living organisms. In the context of the international transfer of technology, the significant consideration is the capacity of the national agricultural research systems of the countries to imitate or adapt technology generated overseas. In this regard, there are important differences between countries in the developing world, with some scientifically advanced countries such as India and Brazil having a relatively strong capacity to copy and/or adapt biotechnologies, while a range of other countries have very little capacity (Evenson and Putman, 1990). As a result, the issue of intellectual property rights is a contentious matter in the Uruguay round of GATT negotiations. Failure to resolve this issue could result in advanced developing countries being shunned by private sector R&D, and having to rely largely if not entirely on public sector research devoted to imitating and adapting technologies developed in the industrialized countries. Alternatively, less scientifically advanced developing countries have an incentive to pass relatively strong intellectual property right legislation, so multinational companies are likely to establish adaptive R&D programmes in such countries.

There is at least one important caveat that needs to be noted with regard to the above projections, and that concerns the role which the international agricultural research centre system (IARC) will play in the development of new biotechnologies for the developing world. Several authors have argued that the main role ought to be to complement private sector R&D by carrying out work on so-called orphan commodities. For instance, certain plants, such as cassava, coconuts and coffee, are likely to be ignored by the private sector R&D system because of lack of ability of Third World producers to pay for advanced technologies, or because imitation costs are too low and exclusion costs too high, or because the size of the market is regarded as being too small in relation to the cost of R&D. Two considerations will be crucial to success in fulfilling this role. One is the outlook for the IARC system not only to maintain its existing funding base, but also to expand it sufficiently to be a significant player in the world biotechnology R&D system. Another is the ability of the system to collaborate effectively with the private sector biotechnology R&D companies in the industrialized countries, or to mount an effective R&D programme in the area of biotechnology if it is not able to secure such collaboration.

Finally, biotechnology in general, and rDNA technology in particular, differs from more conventional technologies because of the widespread public perception that there is a much greater risk of environmentally catastrophic outcomes associated with this form of technology. While the concern with the environmental aspect might be more or less contemporary, a sense of history suggests that public apprehension about the consequences of new technologies during the early stages of their development and diffusion is not unique to rDNA research. Indeed, at least to date, there has been nothing comparable to the widespread social disruption caused by the Luddites during the industrial revolution. Moreover, the net effect on the environment is a highly contentious issue, and many experts believe that genetic engineering will produce technologies which are at worst environmentally benign, and at best advantageous because they significantly reduce the need to control pests and diseases by chemical means. Apart from this possible externality, the potential problems associated with environmental release of genetically engineered organisms would seem to imply a regulatory role for government, but that is a topic for another paper.

NOTES

[1]I am grateful to Rob Fraser for helpful comments on an earlier draft of this paper, and to the Australian Agricultural Economics Society for financial support to attend this conference.

[2]On the basis of available evidence such as that presented above, it seems reasonable to presume that, when private sector R&D firms can appropriate a significant part of research benefits, then sooner or later they will 'crowd out' public sector applied research in the same area. Similarly, Nelson (1987, p. 117) argues that 'The advantages of giving firms incentives, and hands-on capability for innovation can be seen most sharply by considering the poor innovation performances of socialist countries where neither of these conditions exist.'

[3]For instance, see Ruttan (1982, pp. 242–8).

[4]That is, knowledge about specific ways of doing things, or about current operating methods in the industry.

[5]In this paper, the term 'basic research' will be used to describe research where the intended output is simply more information, while applied research will be used to describe the search for new technologies, and which may or may not produce more information as a by-product.

[6]Jaffe (1989) also found that an information externality exists between academic research in universities and corporate patent activity, and that university research appears to have an indirect effect on local innovation by inducing industrial R&D spending.

[7]In terms of their model, basic research on rDNA has opened up a whole new series of distributions of new technologies to search with applied research, or, as they describe it, experimentation.

[8]See Evenson (1974, 1976) for selected case studies.

[9]It is likely that some biotechnologies will be developed which deliberately do not incorporate the characteristic of self-reproduction so as to emulate the precedent of hybrid corn, which does not rely on patents or plant variety rights to protect the intellectual property rights of inventors.

[10]See Evenson and Putman (1990) for a detailed discussion of the distinction between the information discovered by the inventor and that embodied in the device to which patent law provides property right protection against unauthorized reproduction, sale or use.

[11]See Kenney (1986) for an extensive treatment of this topic.

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DISCUSSION OPENING – R.K. PERRIN AND J. BEGHIN*

Professor Lindner notes that the increasing strength of intellectual property rights (IPRs) in biotechnology should have a strong impact on private R&D and that this in turn has implications for the role of public R&D. The message of the paper seems to be that public sector research should *not* be abandoned or distorted by public/private linkages, but there is little positive guidance on what the public sector *should* do. Neither is there any advice about IPRs as a policy instrument, whether they should be strengthened further in the Third World, or weakened in the developed world.

The paper does offer us a synoptic view of the IPR issue as it relates to biotechnology. The issue is whether to have them and, if so, in what form and strength. The accepted economic viewpoint can be summarized as follows. All forms of knowledge have public goods characteristics (knowledge is non-rival in consumption, has low costs of access by marginal users, and tends to have high costs of exclusion), hence there is a theoretical presumption of market failure in the form of under-allocation of resources to R&D. One solution to this market failure is to establish IPRs. Another solution is public sector R&D. Still other alternatives are legal protection for trade secrets, public prizes for new knowledge, and public–private syndicates.

None of these solutions offers a panacea. They are difficult to analyse and compare theoretically because of the myriad possible dimensions of statutes and enforcement mechanisms, and they are difficult to analyse empirically because of the paucity of useful social experiments and the difficulty of obtaining data in any case. In theory, IPRs should increase R&D but they also wastefully limit the diffusion of the new knowledge so created (the appropriability–diffusion dilemma). IPRs might in theory create excessive R&D because of 'patent races' (in the case of negative externalities in the production of knowledge). The most obvious theoretical problem associated with public R&D, on the other hand, is the distortion of incentives that is inherent in bureaucracies.

Lindner's paper elaborates on this summary of received economic wisdom, and describes the evolution of IPRs as they affect biotechnology. In the process of these discussions, he emphasizes three key points with which we would like to take issue. First, he asserts that a key issue for IPRs is whether

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the concomitant restrictions on knowledge transfer will result in a long-run decline in research productivity. Decline compared with what? Presumably, compared to that which would hold without IPRs and only public R&D. His argument is that public scientists exchange information freely, while private firms would disclose only the minimum necessary to meet the 'enabling disclosure' requirements of the IPR system. We think this is an exaggerated concern. But current IPR systems require an enabling disclosure; that is, sufficient information for those competent in the art to be able to 'practise' the invention. In the case of biotechnologies, this frequently includes the deposit of living material to which others can gain access. This precludes a lot of secrecy. Furthermore, it has been suggested that, under the US patent system, the median time-lag for detailed information on new products and processes to fall into the hands of at least some competitors is less than 18 months (Mansfield, 1984). It seems to us that the weight of this theoretical and empirical evidence suggests that the problem of secrecy is at best a short-run problem, with no possibility of offsetting the long-run productivity effects of IPRs, as is suggested by Lindner. The author also seems to minimize the possibility of government failures that could be induced by (public) information asymmetries, institutional design and incentives faced by public researchers. The disclosure of failed innovation attempts is not likely to be reported by public researchers (for instance, 'negative' regression results are not reported in economic journals).

Second, we dismiss his assertion that the unique self-reproduction property of rDNA technologies has crucial implications for (a) the ability to appropriate returns and (b) the utility of disclosure provisions for offsetting the information externality. In the first place, the self-reproduction property is not unique – it is shared by other forms of knowledge which can be 'reproduced' in new applications at very low or zero marginal cost. There are no implications for rDNA because of this self-reproduction property that do not also hold for other forms of intellectual property. The crucial implications for disclosure escape us, unless the author is referring to the potential need for an enabling disclosure to include an accessible deposit of living material, which is indeed important but is already an accepted component of most current IPR systems that affect biotechnology. Professor Lindner could also have related the disclosure issue to patent design (Ordover, 1991) where some patent rules more than others foster early disclosure and diffusion of information (for example, first to file versus first to invent). It would have been interesting to see what design features would be unique or specific to biotechnology.

Third, the author suggests that the public research sector should not be crowded out 'if there are unfavourable externalities or distributional consequences from the use of biotechnologies'. A public reasearch sector could only solve the problem of such 'bads' if public scientists were to invent things that not only avoid the 'bads' but would also be adopted in preference to the 'bad' inventions offered by the private sector. This does not seem very likely. A better use of public funds would be to study the potential bad effects and the potential for government interventions that might avoid them (in other words, hire economists rather than scientists!).

We also have two remarks to make on issues not addressed in the paper. First, the paper could have provided more guidance on the role of the public sector. Some guidance can be found in Scotchmer (1991) for the case of cumulative research. Public basic research is appropriate for the case where the first technology in a cumulative process has low expected profit, while it is valuable for further innovations and where the innovator cannot appropriate the social value of the innovation and its positive externalities. More could have been said also on the state as a facilitator of cooperation and collusive behaviour among firms to integrate/cooperate on technological developments.

Finally, we would like to stress the importance of the role of IPRs in developing country agriculture, as opposed to developed country agriculture. LDCs have the opportunity, by eschewing IPRs altogether, to free-ride on (to 'pirate') technology that is invented in developed countries. Enforcement of IPRs would provide an incentive for invention of custom-developed technology, but it would also subject farmers to payment of royalties on both borrowed and custom technology. Would not a small country (with therefore limited scale incentives for customer R&D), or one with an environmental niche similar to a developed economy (with therefore limited pay-off for customized over pirated technology) be better off as a biotechnology pirate? Just when is it in the interests of developing economies to adopt the IPR systems of developed economies?

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