A Review of Public Policy in Agricultural Research in the United States

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ABSTRACT

Agricultural surplus build up in the international markets, subsidization, and the emergence of new exporting nations has brought about a new challenge to the competitiveness of U.S. agriculture. It is somewhat emphatically stated in the literature that, if *other things* are right, quality improvements will earn the advantage for U.S. produce over the competitors. Towards this end, the capacity of public and private sector research institutions should be geared to produce new technical know-how.

Recent research policy into innovations in biological technology is given prominence in the literature, giving attention to facets such as new production practices in crop and animal physiology, and, in entomology, where the public sector has been the major contributor to new knowledge. The latest debate on patenting of DNA is one area that has received much attention particularly in the wake of discouragement to plant breeding in the private sector. However, most new plant protection technology comes from the private sector as well as new hybrid technology. In terms of **welfare gains**, there is concern over who **gains from private sector research** and development. The same question has been raised as to who **gains from public sector research embodied in private sector products.**

Agricultural technology generation rests almost exclusively in the hands of the public sector in the developing countries and this occurs to a lesser extent in the United States. But, according to sectorial contributions, agricultural research investment in the U.S. public sector is said to be three-folds to what is contributed by the private sector. If there is an interest, a century and a half of public agricultural research in the U.S. awaits to be looked into. Concentrating on the recent past, this review is on two aspects. The **public sector bias in the U.S. policy**, and the **implications for international public research.**

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1. Introduction

1.1 Concepts and Background to the Paper

Agricultural research policy involves principles or actions related to the management of national research in agriculture. The policy indicates a conclusion as to what the role of government ought to be with respect to a particular problem or a set of circumstances. The policy mix of a nation's agricultural research is an important guide to the future research directions.

In the developing world, public policy has a major influence in the supply and demand for agricultural research. But in a developed situation, it is both- the public and the private sectors that influence the capacity for research and research output. This is true to the extent of agricultural research in the United States (U.S.). However, even in this situation the dominant force is the public sector, contributing a major share in the investment and in allocating resources for research. Furthermore, public policy-making in agricultural research both at the Federal and State levels has received the highest priority in the U.S.

New materials developed through agricultural research may be biological, chemical and mechanical. A large proportion of the new knowledge obtained by means of agricultural research is associated with or embodied in these materials in the process of formulating new technology.

The concept of 'externalities' is related here to describe the considerable proportion of economic benefits derived or acquired by groups or individuals which neither carried out nor paid for activity (directly or indirectly), apart from a market transaction. Externalities, thereby, create market failures, i.e. the failure of markets to allocate resources in the best interest of the society. This is a common assumption in the analysis of situations both in the developing and developed quarters alike. The concept is important to determine when and why private firms or groups in society may be motivated to promote, initiate and carry out agricultural research. It is also helpful to gauge the benefits to international agricultural research and in comparisons.

1.1.1 Agricultural research by private funding

Private firms may obtain acceptable economic returns from agricultural research if they are able either;

a) to sell the research results directly or as an element of a product or service,

b) to increase earnings through complementary effects, e.g. if research results contribute to expanded demand for products or service offered by the firm.

In many developing countries, the access to patents and other exclusive rights under legal protection, offer some incentives to the research agencies for acquiring at least some of the economic benefits associated with agricultural research and technology development. However, in many instances effective protection of such rights has been extremely difficult in the past (Pinstrup-Andersen, p.56).

1.1.2 Agricultural research by public sector funding

The consumers of agricultural products are supposed to be the principal beneficiaries of agricultural research aimed at the overall economic benefit of increased agricultural production. For this reason, consumers are either willing or not vehemently opposed to fund such research. Their contribution is indirect through public funds. Public funds for these research are gathered from taxes; both from the consumer as well as the producer. Because of large externalities, a great part of agricultural research is carried out with public funds. Therefore, the question is whether the distribution of costs among individual consumers is proportional to the distribution of research benefits.

1.1.3 Agricultural research by international funding

Certain research with large expected benefits to society will not be carried out by private firms as indicated because most such benefits are considered 'external'. Similarly, certain research activities may not be carried out by an individual country because the proportion of total benefits accruing to that country is insufficient. These research activities are beneficially carried out at the international level. Research, producing results useful for a number of countries for example is suited for international research institutions.

2. The Review

2.1 Public and Private Sector Involvement in Agricultural Research

Due to risk of investment and external economies associated with research, there is a suboptimal allocation of resources to research according to the conventional beliefs. That is, if research is determined solely by individual people and firms responding to market forces. On the same assumption, to off-set the imbalance, the public sector intervenes in the allocation of funds for research namely in three areas.

a) Subsidization of private sector research,

b) Direct public sector involvement, and

c) Introduction of institutional arrangements that encourage research in risky private investments in research, i.e. patenting, biotechnology rights and plant variety rights.

Universally, a very large share of agricultural research is funded by public sector and carried out in public funded research institutions. In the United States for instance, atleast two- thirds of agricultural research activity is conducted in the public sector (Ahmed and Ruttan, p.122). In most countries the share of private research is much smaller (ibid).

U.S. Federal involvement in agricultural research and technology has been a mixed rationale. Initially, it was designed to benefit farmers by increasing their productivity and solving their problems as they rose. According to Knutson et al (1989, p. 393.), agribusiness benefited from the increased proportion of farm costs spent on purchased inputs. Therefore, the ultimate beneficiary of public research was the consumer who received an abundant-

-supply of food with a decreasing proportion of income spent on food. Considering two successive Farm Bills (of 1985 and 1990), the longer-run agenda for public research has a primary goal of sustaining the base of natural resources to assure a continuing supply of food for future generations. To this dimension, Knutson (p.67) adds 'agricultural establishment has lost control of the farm policy agenda since 1970'. This he attributes to consumer interest in the decisions of U.S. department of Agriculture (USDA), the influence of the Secretary of State in international food issues as the Secretary of Agriculture, and since the Secretary of Agriculture cannot consider only farm interests in decisions on agricultural and food policy.

According to Edwards and Freebairn (1981, p.2- largely on the Australian scene), 'the private sector can be expected to involve in research where benefits are relatively easy to capture rather than involving in research where appropriation of gains is much harder'. Demonstrated easiness in research investment normally occur in the private sector in areas such as agricultural machinery and plant chemicals. On the other hand, less enthusiastic investment occurs in biological and process oriented research in the private sector. On the global situation, Ahmed and Ruttan (1989, p.108-9) demonstrates, research and development leading to new knowledge and technology has clearly been important in growth in total productivity among other important factors.

2.2 Patenting Research Products and Processes in Agriculture

Both the private and the public aspects of technology are built into the patent system nationally, and at other times internationally.

Under patent law the lure and reward for agricultural invention (research outcome) is a temporary and limited legal right to control use of the invention (Nelson, 1987, p.73). In exchange, Nelson adds; 'the inventor discloses the invention and what makes it work, and agrees to abandon proprietary control after a certain number of years.

Both aspects of technology, i.e. private and public, are theoretically explained in economic models by various authors. Some have seen the lure and reward for innovation in capitalist economies in the quasi-rents on the private temporary monopoly associated with the introduction of a new product or process. This is the private side of the story.

On the public side, some have reflected on a temporary monopoly situation to the introduction of an innovation. The gains to an innovator are limited because, sooner or later, competitors will be able to imitate, or invent around, or develop a better version of, the initial innovation (ibid, p.74).

2.2.1 Property rights in biotechnology in developed nations

It has been said that biotechnology 'concerns the creation of new varieties of plants, new animal breeds and new microorganisms, either by traditional selection methods or by new methods of genetic engineering, that is by methods of modifying the genes of animals, plants and microorganisms, by introducing an artificially modified genetic material,' to provide new products- plants, and animals and microorganisms, as well as parts and by-products thereof- and new processes for using or producing such products

2.2.1.1 Regulation of biotechnology

Biotechnology's definition has been a fundamental issue which affects the scope of regulation according to Offutt (1987). So long as new techniques, like cell fusion, are considered to older technologies, the issue of new regulation does not arise. According to the developments taking place in the U.S., industry fears that, if biotechnology were perceived as posing new problems, more regulatory control would result. Some of the Federal agencies involved in monitoring biotechnology research in the U.S. are; the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), the National Institutes of Health (NIH), and the U.S. Department of Agriculture (USDA). According to these agencies, biotechnology fall into three categories:

1) classical genetic selection or breeding,

2) the direct *in vitro* modification of genetic material, and

3) the use of other novel techniques for modifying the living organisms.

They propose the distinctions among the categories to detect and circumvent any potential environmental risks.

Patent protection for innovation in biotechnology research must also be noted with interest. In the wake of a landmark case in the Supreme Court of the United States in 1980, it became evident of the opportunities for protecting the exciting, new advances in biology.

There is widespread agreement now that 'biotechnology' involves uses of, or organic changes in, animals, plants, microorganisms and any biological material that can be assimilated by living matter (Bent et al 1987, p.1). But beyond that broad definitional consensus, there lie profound differences dividing the nations over how, or even whether, the diverse fruits of biotechnology should be protected.

'The legal principles that govern the protection and fostering of innovation enjoy a degree of universality that is remarkable in the field of international law. In Many respects there is substantial agreement, particularly among the developed countries, as to range of patent protection is warranted, the criteria for granting such protection, its duration and the circumstances under which rights to patents may be perfected internationally. The extent of this consensus is evidenced by the 97 nations which are now members of the Paris Union for the Protection of Industrial Property, one of the oldest multinational treaties still in force' (ibid, p.2).

Under the provisions of the international union, countries have the right to make separately between them special agreements for the protection of industrial property, insofar as these agreements do not contravene the provisions of the convention. Number of special multilateral agreements between members of the union have sprung since this development, some of which affect biological inventions. For example; the European Patent Convention, the Patent Cooperation Treaty, and the Budapest Treaty (currently 19 members) regarding the deposit of microorganisms are off-shoots of the main convention.

International depository authorities and the Budapest Treaty

Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the purpose of Patent Procedure which entered into force in 1980, provides as a principal objective that member states recognise for their own patent procedures a deposit of the microorganism strain made in another country. It is open to membership for any country belonging to the Paris Union convention. This treaty contains a special provision under which any intergovernmental organization having authority to grant regional patents to several countries. The backbone of the Budapest Treaty is the provision for a series of International Depository Authorities. While United States is a member of the Paris Union, and the Budapest Treaty, Australia has the membership only in the former union.

2.2.1.2 Problems facing patenting in biotechnology:

1) How should traditional standards governing protectable subject matter be applied to innovations of biotechnology that necessarily involve the modification of 'natural systems of living matter'? For example, when does a connection with living matter, a common feature of all biotechnological inventions, cause a given innovation to be characterized as 'a mere discovery' or 'essentially biological' or 'a product of nature'?

2) What considerations should influence one's choice among the various descriptive levels- morphological, physiological, genetic and molecular- available to characterize a biotechnological invention so as to satisfy existing requirements for disclosure of patentable subject matter? By the same token, it is pointed out as to what sort of disclosure of biotechnological invention is legally sufficient when the invention involves manipulating animate starting material that cannot be reduced descriptively to its constituent elements?

3) What are the appropriate limits of protection afforded a biotechnological invention that both is self-reproducible and contains biological information useable in other biotechnology innovations?

2.3 Situation in the United States

A patent may be obtained for 'any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof.' Unlike in many other countries, there is no statutory exclusion for specific subject matters. Concerning protection of biotechnology, the U.S. Supreme Court held in a landmark decision that an invention is not precluded from patent protection under a Section of its law because it consists of living matter. The test for patentable subject matter in this field is whether the invention is the result of human intervention. Since that decision, the Patent and Trademark Office (PTO) has adopted something of a 'case-by-case' approach in deciding the patentable status of different kinds of biotechnological inventions. In 1984, the PTO took the position that patent protection was precluded for plant-related-inventions that could be protected under the U.S. plant protection laws. In 1985, this policy was repudiated and the PTO announced a policy refusing to grant patents for animals. This policy too was repudiated due to claims that 'polyploid Pacific oysters' were directed to 'non-naturally occurring manufactures or compositions of matter within the confines of patentable subject matter'.

The Plant Patent Act (PPA) provides for the protection of asexually reproduced plant varieties (other than tuber propagated or plants found in an uncultivated state). The provisions of the general patent law apply except that the description of the plant need only be 'as complete as reasonably possible.'

No trialling or testing is required, nor do deposits of plant material have to be made to ensure the maintenance of the germplasm. The term of the plant patent is likewise 17 years as in the case of patenting microorganisms, and there is no provision for compulsory licensing.

The Plant Variety Protection Act (PVPA) was enacted in 1970 to provide protection for sexually reproduced varieties. PVPA is administered by the Department of Agriculture and the conditions are that the variety must be distinct, uniform, and stable, and a varietal name must be given. Seeds must accompany the filing of the application, and a viable quantity must be maintained during the term of the certificate. The term of protection is 18 years, and the owner has the right to exclude others from selling the variety, reproducing it, or importing or exporting it. There is a farmers exemption which gives a farmer the right to save seed produced from protected seed for purposes of growing crops on his farm or to sell to other farmers for growing crops. There is also a research exemption, which permits the protected variety to be used for breeding or other research without infringing the protected variety.

2.4 The Australian situation

The Australian Patents Act of 1952 defines an invention to be 'any manner of new manufacture.' This has been interpreted to include articles, apparatus, processes, and methods other than those for controlling a manufacturing process involving mere working directions. The Patent Office specifically excludes from protection: a) substances that are capable of being used as food or medicine, and that consists only of mixtures of known ingredients; and b) the processes for producing them.

In 1976, the Australian Patents law held that living organisms are not excluded from patent protection. Specifically it spelt that a new microorganism with man-improved or altered useful properties is patentable. Patent Office practice since then appears to permit, atleast in theory, patent protection for all categories of biotechnology, including pure cultures of a naturally existing microorganism. The criteria to be met before an application concerned with living organisms will be accepted are precisely the same as those for any other application, i.e. no distinction is to be made solely on the basis that a claimed product or process is, or contains or uses, a living organism. Higher life forms will not be treated any differently from lower forms such as microorganisms. The Patents Act requires a full description of the best method of performing the invention. In this regard, it should be noted that disclosure of a method of performing the invention, i.e. producing a new organism, which by repetition will again produce the organism, is required.

The Patents Office has issued patents to new plant varieties in keeping with the above law. However, no attempt has been made todate to obtain similar protection for animals. Future decisions to grant patents for new animal breeds or genetically engineered animals may be influenced by a provision in the Patents Act that, via the statute of monopolies, prohibits the grant of patents for inventions that are 'generally inconvenient.' It could be argued that this provision requires the Patents Office and courts to take into account questions of public policy when determining the patentability of inventions for higher life forms.

3. Economics in Agricultural Research

Touching on the history of diffusion of information it is said "in American society points to changes that were affected less by technology and specific actors, and more by cultural and ***economic events*** that were spread across several generations." Brown, (1989, p.295) adds further, "the speed at which information travelled across space was ultimately less important than the question of whom it touched as it moved through society".

Economic returns to research differ from returns to other economic goods in many ways. There are important differences in the ways the benefits accrue in each case. To ascertain the largest possible benefits from research, knowledge of the most important differences between them is an essential factor (Per Pinstrup-Andersen, 1982 p. 24). Information of that kind is also vital not only in the allocation of public funds to agricultural research, but in the case of assessing under what circumstances international research is useful.

Estimating the value of agricultural research and technology is perceived as difficult and is considered associated with large uncertainties. However, many studies have partially tackled the issue of estimating economic returns from research programmes. Pinstrup-Andersen (p.100), have gathered returns to some 50 specific agricultural research programmes worldwide including Grilliches' hybrid maize in 1958 to Schmitz and Seckler's-tomato harvest in 1970. Similarly, Ahmed and Ruttan (p. 109-15), through 58 agricultural research ventures of various nations, shows how calculations of annual internal rate of return can be useful in analyzing the contributions of research to increased agricultural productivity.

4. Public Policy Developments

Using newly developed time series on U.S. public sector, Pardey et al (1989) have demonstrated substantial differences in measuring real resource allocation to agricultural research. They have also contrasted measurement of resource allocation in agricultural research from 1890 to the present using real research service *flows* as opposed to real research expenditure. They put together somewhat a quantitative analysis to research spending in the dominant public policy area in the U.S.

Now to counter that with a qualitative summation of a review on U.S. agriculture in recent years, the basis for this paper. Knutson et al (1990, p.392), describes the economic malaise in parts of U.S. agriculture in-

-recent years which has caused some agriculturalists to question the benefits of continued development and diffusion of technology. One view is that investments in research leading to further technological advancement should be curtailed because there are agricultural surpluses. Another view is that research should be reoriented toward reducing costs rather than increasing output. A third would limit transfer of technology to foreign countries.

Continuing on the above value judgements, any reduction in research spending would have little effect in the medium term time horizon. However, it could have serious negative effects in the longer term to the future productivity and competitiveness of U.S.produce in world markets. Firstly, attributing economic surpluses to research and technology must be ranked lowly amongst other contributing factors such as rigid, poorly constructed farm policies, economic policies that constrain demand in domestic and foreign markets, and protectionist policies both abroad and at home. In actual fact, compound growth rates for research expenditure constructed by the OECD (1989, p.19, Table 1), indicates there is a downward trend in the spending for U.S.

	Period		
	81-85	83-85	85-87
United states (%)	6.1	7.3	4.0

Secondly, the suggestion that research should concentrate on technologies that reduce per unit costs of production rather than output is a non sequitur (opcit). 'Given the competitive nature of agriculture, technology that reduces per unit costs will, in all likelihood, stimulate agricultural output relatively quickly'.

Thirdly, the concern about transfer of U.S. generated agricultural technology to foreign countries arises from the contention that such transfers erode its competitive position in world markets. Infact, one positive suggestion by the U.S. agricultural economics research is that the competitiveness can only be enhanced through qualitative improvements to its produce that sell in the world markets to gain the much needed comparative advantage. This can only be facilitated through competitiveness in new agricultural technology aside border considerations. One journalist has wisely queried; 'if there is a barrier to foreign transfer of technology, what can be done to ensure that U.S. agriculture benefits fully from its own-generated technology?'.

Analyzing the structure and growth of international technology transfer by the OECD (for 1975 and 1985), one could find a different story of the actual position for the U.S. which is by far the major supplier of technology transferred abroad. In absolute terms, U.S. payments have declined by $528 millions from 1975-1985 period. For the same corresponding period, the U.S. have gained an increase in its share of receipts from transfer of technology abroad to the tune of $642 millions.

The need to supplement national research and development results by importing foreign technological knowhow is a common characteristic of OECD countries, according to OECD science and technology indicators. The report (1989, p.35) further adds; '...it furthermore reflects the inability of even advanced countries to participate all technologies desired by the home market.'

Receipts and payments for internationally transferred technology, 1975 and 1985

In million US $ at 1980 prices and exchange rates

	Receipts 1975	Receipts 1985	Payments 1975	Payments 1985	Balance 1975	Balance 1985
OECD total	9882	12662	7751	9437	2131	3225
USA	6207	6846	683	155	5524	6691
JAPAN	373	949	948	1188	-575	-235
EEC	3118	4396	5409	7191	-2291	-2795

source: OECD, R&D, Production and Diffusion of Technology1989

From the above table, it is quite apparent that the U.S. has had a net gain of 5524 and 6691 $ million in 1975 and 1985 respectively from the exchange of technology across the boundaries. Although, the research budget (as follows) for agriculture in 1985 for the U.S. represents only a fraction of the the total public spending, the tendency for trade only encourages more exports of agricultural knowhow if it were to follow the leads.

United States Budget of Government Agencies
(million $)

30332.4	DEFENSE
5834.4	ENERGY
5493.6	HEALTH
3561.6	NASA
1419.1	NSF
983.6	AGRICULTURE
410.6	TRANSPORT
403.0	COMMERCE
395.9	INTERIOR
320.4	ENVIRONMENT

(source: OECD 1989, p.29)

In pursuit of what level of intervention is desirable in the U.S. situation, people like Hadwiger argue with empirical evidence that there is an opportunity for the private and public sector to jointly invest in agriculture. Others have shown (for example in Browne, 1988) how lobbying and intraorganizational pressures affect strategies and tactics in the policy domain. In here, the Canadian experience must also be noted. Klein and Furtan (1985 p.98), suggest they introduced the notion of the private rate of return on public investment generally and on the private contribution to public research. According to the literature cited, it is difficult to find public sector research in either the developed or developing economies that have exerted a significant impact on the progress of mechanical technology in agriculture. Perhaps with less force, a similar comment is found in the area of post-harvest technology.

The private sector has become a dominant contributor to improved seed varieties, hybridization, and improved genetic materials. Public sector is still the main source of inbred commercial hybrids in the U.S.

4.1 U.S. Farm Bill and Public Agricultural research

4.1.1 The 1985 Farm Bill

Agriculture's entrance into the era of biotechnology and information technology raises questions about the impact of technical advances on the performances of the research system and the affect on the structure of agriculture. According to OTA (1985, p.68), the USDA research should concentrate on those agricultural problems that are important to the Nation and for which no one State or private group has the resources, facilities, or incentives to solve. Such a role can be assigned to USDA Agricultural Research and Economic Research Services. The land grant university system was founded as an alternative to fulfill the need for decentralized public research. As the current magnitude of private sector commitment to agricultural research is largely unknown, studies estimate it to approach $ 3 billion. Since property rights to patenting has emerged as an issue, land grants research system would have to adjust to this new concept of research law- namely exclusivity.

4.1.2 The 1990 Farm Bill

Since the previous Farm bill and the success it entailed, the preparatory work has been continuing in the U.S. Congress for the upcoming farm legislation. In a Presidential address (USIS, 1990), it is stressed, on the development of a 1990 Farm Bill that enhances competitiveness of American farmers. As in the case of 1985 Bill, it is proposed to counter the resources issues in the coming Bill in 1990, which may eventuate actually in 1991. The bulk of the research effort is directed therein towards protecting the nation's surface and groundwater resources from contamination. The House of Representatives took that approach in late 1987 when it passed a $500 million groundwater research bill. *Low input sustainable agriculture* is another approach to research envisaged in the preparation stage of the coming farm legislation. Many are patterned after the strong conservation provisions in the 1985 farm bill. Global warming is another vital aspect about the environment that has been dealt with in the recent congressional proceedings (U.S. House of Representatives, 1989, p.21). Thus, research efforts would encompass these crucial environmental issues to facilitate agriculture's stability.

4.2 Research Policy and Primary Industries in Australia

According to a government policy statement (Commonwealth Government, 1988, p.23), the Australian government considers that the implementation of the results of research is of high priority. The government also believes the public sector will continue to play a key role in the funding of research in all areas of primary industries, resources and energy. Because of the complementary nature of research domain, an integrated approach is - envisaged for resources in Australia. Coordinated approach to Natural Resource Management will involve, soil, water and trees and will review incentives for conservation on farm.

4.3 The Incidence of Public Sector Bias in Agricultural Research

The fact that technology goes public has three benefits. It assures that a healthy share of the benefits of an innovation goes to users and dead weight losses of restriction are only short-run in nature. Knowledge of the new research product or process provides a base and creates opportunity for further innovation to others. By facilitating subsequent competition, monopolistic situation is kept under control.

In some nations, plant breeding by private sector is actively discouraged. The traditional rationale for public sector agricultural research is that individuals had little capacity to conduct research. Ahmed and Ruttan explains, little possibility to realizing a significant share of any gains from the results of research. The difficulty and establishing effective proprietary control over research results are the main reasons for limiting private incentives to conduct agricultural research.

4.4 The Case for International Public Research

Despite the adversities created by the rapidly expanding food production and mounting food surpluses on an international scale, Hadwiger and Browne (1987) argue for a vital role for agricultural research into the 21st century. Thus agricultural research, playing center stage in this world food situation, has become both a miracle worker and villain in the eyes of many onlookers. By providing more abundant and inexpensive food for the world's numerous consumers, by extending ***this*** technology into developing nations via international public research institutes, and by working toward an environmentally sustainable technology, the public agricultural research system has enhanced its political legitimacy. Having gained 'political legitimacy', research institutions should now seek for more support on the national and international level.

Future investment in International Agricultural Research Centres and much of the investment in national research programmes in developing nations will have to depend on international bilateral and multilateral aid. Judd et al (1986 p.109) shows such a pattern of behavior in the past in the developing world. Since 1959, there have been much progress in developing research capacities in these settings with much of the international public research participations.

4.5. Implications of Advancements in Agricultural Research

4.5.1 Technological changes and resources crisis

Technology is one aspect that creates agricultural growth. Looking at the prospective patterns of technological change in agriculture, there is much scope for high agricultural technology to replace the existing technology. However, it has not yet replaced conventional plant breeding and conventional ways of improving livestock. The major contributions have been in livestock industry, particularly in biologically controlling livestock diseases and growth. The advances also reflect simpler life processes for the generation of antibiotics, hormones, and other substances previously-

-producible mainly by using live, whole animals. According to researchers like Hildreth (et al), massive genetic reconstruction of whole animals is still something for the future, and for the most part, the same is true for massive reconstruction of whole plants through molecular microbiology.

Research advances in agricultural engineering, encompassing procedures to complement and make it possible to farm the more fragile soils that will have to be farmed in the future, will be crucial as well as water-saving irrigation systems.

Water looms as the major agricultural resource crisis turning into the 21st century. Agriculture is the main user of water mostly for irrigation. In 1980, according to study by Beldon (and others, 1986), irrigation has accounted for 83 billion of the 100 billion gallons of fresh water consumed each day in the U.S. Of the 1,260 billion gallons of water flowing daily into the nation's streams, 315 gallons are withdrawn. But most of this total is returned to the streams; only 96 billion gallons a day are consumed. Agriculture accounts for most of that water consumption. The fact that irrigation has successfully converted millions of acres land into productive farms cannot be treated isolately, considering the many environmental problems it has created. As stated above, irrigation has been the foundation for economic growth in agriculture. At the same time, irrigated area has risen substantially since 1900:

Year	Acres (millions)
1900	7.2
1930	14.6
1945	20.7
1955	30.0
1975	45.3
1978	51.3

source: Beldon, p.68

The increase in the area managed under irrigation has risen dramatically, and at the same time has created problems in three environmental fronts;

1) depletion of water resources,

2) salination, and

3) land subsidence.

Present Federal policies have subsidized irrigation to such an extent that very cheap water has been made available (ibid, p.71). With resource crisis looming, and sustainable issues pursued under the Farm legislation, unlimited access to water is coming to an end. Policy should help develop conserving technologies. Such technologies like canals lined to move water less wastefully, introduction of sprinklers in preference to flooding, drip irrigation to direct water to plant-root systems, will have much significance in the research agenda in time to come.

5. Conclusion

The paper consisted of a review of literature on the public policy in agricultural research in the United States. It also took into account of the recent developments in the policy domain in particular, the two Farm Bills and congressional proceedings surrounding the directions of U.S. research policy. Theory basically consisted of the ideas flowing from Per Pinstrup-Andersen, Hadwiger, and Browne, whereas shaping of political arguments consisted mainly from Browne. The latter also was incumbent on the political economy of international public research. As usual, Ruttan was the key to empirical verification of economic theory in practice in international agricultural research and he was well supported by Ahmed in place of usual Hayami.

However much the practicality is concerned, the U.S. experience suggest, there is an ever increasing role for the public sector to perform in shaping the agricultural research agenda in the long-run horizon. Judging from the concerns at the Federal level, the Farm Bill has been the key legislation to look upon for direction in research policy since early 1980's. The refurbishment of the future policy will also be much in line with the incoming farm legislations that will guide the flow of funds which is the key to research well into the next decade. Taking inference from the 1985 bill, the ground work for the 1991 bill sheds much light on the low intensity sustainable farming which is the key to bring farming in line with scientific management of resources or in other words to come to terms with the realities of working in harmony with mother nature. This, the U.S. takes not only the pride, but the lead to sustain its superiority in agricultural production. That is why the concern is now on the global warming and the research priorities surrounding it. The water resource has received the closest attention this time around at the highest policy- making levels. It was the soil last time around. Naturally, the directed research policy also revolves around these concerns.

Whether it is the private sector or the public sector has not been the concern in putting into practice what is given by the highest policy levels. In governing the agricultural research policy in the U.S., it is the public concern which has been dominant. But, there is options for the private sector to reap harvest if wanted by collaborating with the public ventures or to venture into research products or processes. Atleast the legislation supports this. However, by keeping a control over patents, the public *interest* can be met whether at selling a research product, or producing one within or outside the U.S. Who should decide these vital decisions still remains to decided. The overwhelming dominance in the transferring of research *produce* abroad allows the international policy to be dominated at the hands of the U.S. How much involvement, or what should be sold to outsiders or given for nothing also remains in the hands of the highest political level. More than at what price, it is the vested interest or the *politics* that matters in shaping the agricultural research policy for United States and for that matter the International Agricultural Research.

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