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EFFICIENCY AND EQUITY ISSUES IN *EX ANTE* ALLOCATION OF RESEARCH RESOURCES

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Economic Research has now amply demonstrated the very attractive rates of return to agricultural research.[1] The process of research resource allocation has so far been mostly informal and based on scientific judgement of researchers and research administrators. "At higher levels, the judgements are partly scientific and partly political. There was agreement . . . that the high rates of return from past research imply that the subjective judgement of knowledgeable scientists and science administrators should receive good marks."[2]

The convincing evidence on research pay-offs has enabled national and international agricultural research systems to convince policy-makers to allocate more resources to research; as a result agricultural research systems are expanding in most developing countries. Therefore, the optimal allocation of research resources to commodities, regions and factors of production will become more complex as the most obviously high priority projects are provided with adequate funding.

The stock in trade of most economists has been *ex post* analysis of research pay-offs and distributional outcomes. *Ex ante* research resource allocation problems have nevertheless received some attention. We firmly believe that it is time to further change the emphasis of economic research in this area from *ex post* research to *ex ante* research, and that this should be done both at the individual programme level as well as at the regional and national levels with very close interaction between the biological-technical scientists and the economists.

Most economic investigations into the *ex ante* research resource allocation problem have been concerned with formal decision models. Such models have been created and sometimes computerized for firms engaged in research, for agricultural research stations, and for entire agricultural research systems.[3] Most of these models take as their objective the maximization of returns to

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1. Arndt and Ruttan, 1975 and 1977; Herdtford and Schmitz, 1977; Boyce and Evenson, 1975. Rates of return are attractive for successful research projects but also for entire research programmes which include failures. They are high in the developed countries but even higher in the developing countries, indicating an even more severe under-investment in research in the latter. Rates of return are high to applied research but also to research in the agriculural support sciences of genetics, pathology, entomology, etc. (Boyce and Evenson, 1975; Evenson and Binswanger, 1977). This contradicts the common belief that more basically oriented research is unproductive. Finally, the empirical evidence stresses the limited transferability of agricultural research results across regions and thus puts emphasis on national and local research capacity as a crucial link in the agricultural research process.
2. Arndt and Ruttan, 1977, p. 20.
3. For a review of these models, see Schumway, 1977. Fishel, 1971 discusses a computerized model for an agricultural research station.

research for investments without looking at other social goals. However, as the general emphasis in economics is shifting from national income to income distribution, nutrition and other quality of life aspects, research resource allocation models to take these aspects into account have also been constructed.[4]

The most ambitious effort at conceptualising research resource allocation with multiple goal is by Per Pinstrup-Andersen and David Franklin (1977). They argue forcefully that the role of economic research in research resource allocation is to link final social goals such as growth, equity and security with immediate working objectives for the agricultural production scientist which must be expressed in terms of yield targets for specific crops, other yardsticks of technical efficiency, desired product characteristics or production risk. They then propose a formal model which proceeds through logical stages: (1) identify reasons for low productivity, (2) identify researchable problems which, when solved, will improve productivity, (3) estimate the impact on production of solving each of the problem, (4) estimate the probability of research success, the likelihood of the results being adopted, and the time required for solving the problem, and (5) estimate the impact of alternative research results on product supply, input demand, farm income, income distribution and farm size.

The sequence of steps in the model is unexceptionable. In particular, the emphasis on identifying the causes of low productivity at the farm level and linking them to researchable problems is of overriding importance, as well as obtaining some idea of the probabilities of technical success. Good access to a farm level data base and an opportunity to join with tehnical and biological scientists in farm level observation and diagnostic experimental work are essential for successful work on problems (1) and (2). However, step (5), if taken seriously, could require a detailed model of the agricultural sector including its links to the national and international economy. The use of such formal models can thus at best be advocated for a national research agency which desires to improve its research resource allocation process or for the international allocation of research resources.

At the national level, and particularly at regional or research programme levels, it may be more appropriate to use simpler tools of benefit-cost and partial equilibrium analysis to strengthen the already existing informal allocation process. Most questions faced by research administrators do not concern the fresh allocation of an entire research budget to a new portfolio of research projects. Instead, in existing institutions, research decisions are taken sequentially over the development of the institution and are of the form: "Should the effort in this direction or that direction be increased, decreased or left constant, and how large should the changes be?" Such marginal research resource allocation problems are well suited for analysis with standard tools. The economists' effort at providing information which

4. Some of this work will be discussed in a later section.

is useful for such choices is of a less overwhelming magnitude. It requires less of the very scarce sophisticated analytical skills and is likely to be accepted by the biological and technical scientists far more easily than grandiose attempts to set priorities for entire programmes and institutions. It also lends itself much more to informal interaction among disciplines because scientists can more easily understand the cost-benefit and partial equilibrium analyses than full general equilibrium models of entire sectors.

The remainder of the paper is devoted to a discussion of basic elements of research resource allocation decisions and gives a few examples of how to take them explicitly into account. Research productivity issues are covered first followed by distributional questions.

EFFICIENCY ISSUES

(1) *Scale of Output*

Research is an activity with increasing returns to scale, not in the production of research results but in its application. This arises from the fact that once discovered information or a new variety can be applied to additional land areas without additional research costs but only with diffusion costs such as extension or seed multiplication. Thus the benefits from research are directly proportional to the area on which it is applied. From this property stems a simple rule of thumb for commodity allocation of research budgets: The share R_i of the research budget going to commodity i should be proportional to the share of the commodity in the value of total output of a region or a country considered. This rule of thumb is surely not optimal, but it can often serve as a good initial yardstick to see whether a research budget is approximately in line with a product mix.[5] Deviations from the rule can then be justified in terms of potentials or side effects.

An example where such corrections are necessary are with new crops. It was found that in oilseed research in India the budget shares for sunflower and soybeans by far exceeded their shares in the value of output while the groundnut's share was very low. Implicit in such an allocation is the belief that adaptive research on the new oilseeds will lead to faster and more widespread success than research on the established crop groundnuts. Such

5. Boyce and Evenson, 1975 used their data on research expenditures of national systems to test how well this rule is satisfied. They compute an index of congruence of the research budget shares with the shares of commodities in national income. (Congruence $= 1 - (\sum_i C_i - R_i)^2$ where C_i and R_i are shares of commodities in output and research, respectively.) They classify countries into per capita income groups and show that in 1959 the highest income countries achieved the highest levels of congruence whereas the lowest income countries achieved the lowest levels, pointing to serious misallocation of research resources to commodities in the latter. This was surely a remnant of the inordinate emphasis of colonial research systems on plantation and export crop. By 1971 congruence had increased in all countries, including the lowest income ones, showing that earlier imbalances were being corrected.

implicit judgements become apparent by the rule of thumb and can be subject to greater scrutiny.

(2) Exhaustibility of Research Pay-offs

In their chapter on "A Stochastic Model of Applied Research," Robert Evenson and Yoav Kislev (1975) treat applied research as a sampling process, using seed research as an example. They assume that at any given time, nature and the state of basic sciences and of plant breeding technology determine a probability distribution of potential yields. This distribution defines the potential pay-offs to applied research. The applied researcher cannot affect the parameters of this distribution, although his skills determine how effectively he samples the distribution.[6]

Applied research is then viewed as drawing successive samples from a given distribution of potential yields. Once a sample of a given size is drawn, the research pay-off is the *difference* between the sample point with the highest yield and the yield of the currently used variety. All other sample points, except the highest yielding one, are immaterial and are disregarded. The *expected research pay-off* is thus the first-order statistic, or the largest yield increase of the sample. When one solves the Evenson-Kislev model of applied research, it is immediately clear that the optimal sample size or research effort will be larger, the lower the current yield relative to the mean of the distribution of potential yields, the larger the variance of this distribution and the larger the area planted to the crop. These characteristics are general: The farther back you are relative to the potential achievable by research and the wider the distribution of the character for which you search, the higher the potential pay-offs.[7]

The model also points to the basic exhaustibility of research pay-offs. As long as the potential yield distribution stays constant it will become more and more difficult to find further yield increases after an initial increase has been obtained. The probability that sampling will lead to further gains beyond the point reached declines, the larger the yield already reached. Thus either larger research efforts are required (with lower benefit-cost ratios) or the potential yield distribution has to shift. The latter can come through breakthroughs in genetics or breeding techniques, through new germplasm discoveries and interspecific hybrids, or through other advances in the basic or supportive sciences. While the supportive sciences have no directly measurable effect on yields, a continuous stream of such advances is crucial for the maintenance of productivity of applied research. Exhaustibility and the breaking of it via basic advances has been a very prominent feature

6. The issues related to how the skill distribution available to a research system at a given time affect research resource allocation are discussed in Boyce and Evenson, 1975. Other research management issues which determine how the basic research potential is actually used are discussed in Mosemann, 1977 and 1970. We will not further discuss such management issues here.

7. Plant breeders are well aware of the fact that breeding for characters which do not have large variability in the germplasm is not likely to be successful.

of plant breeding history and the importance of the phenomenon is fully documented.[8] Research resource allocation at the macro and micro level has to take account of it.

(3) Location Specificity

Location specificity of agricultural research on account of variability in the biological environment no longer needs any documentation. Nevertheless, its implications for research resource allocation have only recently been realised.

Biological research can be viewed along a spectrum from very applied operational research at farmers' field levels to very basic research in supportive sciences such as genetics. Results at the basic end of the spectrum have a very wide transferability across agro-climatic regions and sometimes even zones, while management practices and cropping systems vary enormously across locations.[9] At the same time, the level of research skills required for adaptive crop management trials in farmers' fields is lower than those required at the basic end of the spectrum. In fact, there is ample evidence that farmers experiment themselves and find local adaptations of management practices and cropping systems fairly rapidly, provided that they can observe the effects easily.[10] This points to the necessity and rationale for organizing research efforts on a main-station branch-station basis.[11] Furthermore, it indicates that agronomic and cropping systems research can have its highest pay-offs in large homogeneous zones where the quicker discovery of efficient management techniques for new technologies by formal experimentation rather than informal farmers' trials can be applied over a large level of output. On the other hand, where many different and small zones exist, benefits to such management and cropping systems research may be very low and one may have to rely on farmers' own informal methods.[12] It must be emphasized that for all research efforts whose results are also eventually found out by the informal trial and error process of farmers, benefits are restricted to the number of years gained through formal research over the trial and error process.

Finally, the lower location specificity of varietal research than agronomic or systems research or of basic research versus applied research implies that a region or research programme which invests in less location specific research

8. Evenson, Houck and Ruttan present an early historical discussion. Evenson, 1977 presents additional historical cases and recent empirical evidence. Evenson and Binswanger, 1977 discuss the exhaustibility issue as it relates to the pay-off of basic or supportive research in more detail.

9. For documentation of the variability of optimal fertilizer, see Ryan and Perrin, 1973.

10. For example, in a sample of 30 households in one village of Sholapur district we found 60 different systems of intercropping and patch cropping, indicating an extraordinarily fine adaptation of the cropping systems to minor soil and weather variations (Jodha, 1977). Farmers' experimental efforts become ineffective where simple observation is inadequate, and where specialised scientific skills and laboratory techniques are required, as in analysing micronutrient deficiencies in soils.

11. See also Binswanger, Krantz and Virmani, 1976 for implications for international research institutes.

12. For a discussion of these points in the case of Nepal, see Binswanger, 1976b.

will contribute to other regions as well, *i.e.*, not capture all of the research benefits itself. This may explain why less emphasis is given to basic research by locally rather than nationally or internationally funded research efforts.

(4) Comparative Advantage of Private versus Public Research

The effectiveness of privately funded research is an issue which is frequently neglected in research resource allocation debates. It is closely tied to three issues: The appropriability of research benefits, the riskiness of research and the skill level required to achieve results. Private firms will not invest into research unless they are sure to reap the majority of benefits of the research. Thus private research is concentrated on appropriable products such as fertilizers, pesticides, herbicides, mechanical equipments and hybrid seed. Results are embodied in a product and for reasons of patent protection, brand preferences, or decay of genetic viability, have to be bought from the researching firm or its licensee. Furthermore, private firms tend to concentrate on the less risk and more appropriable applied end of the research spectrum.[13] Publicly funded research thus should concentrate on complementing private research in these areas.

The basic advances of mechanical equipment applicable to developing countries are probably now exhausted. What is required is adaptive type of engineering. It appears that in contrast to biological adaptive research, the skills for mechanical adaptive research are not necessarily acquired in formal training. Inventive farmers and mechanics often seem to be as capable as highly trained engineers and are frequently more cost conscious. They are also much more numerous and thus provide publicly funded research efforts with a competition which has resulted in very low adoption rates of machines developed by publicly funded agricultural machinery research efforts. This is a world-wide phenomenon and not peculiar to developing countries.

(5) The Role of Factor Scarcities

Hayami and Ruttan (1971) in their work on induced innovation draw attention to the fact that different factor scarcities have led to different technology paths. Technology development in Japan has economized primarily its scarce factor, land while U.S. technology development has been oriented towards saving increasingly expensive labour. Further tests of the induced innovation hypothesis on much larger and different data sets have largely confirmed the impact of factor scarcities on technology development in agriculture and clarified the mechanisms by which farmers or other interested groups bring pressure to bear on public research system to provide them with the desired technologies.[14]

13. For a documentation from industry, see Mansfield, *et al.*, 1971, Chapter 2. In U.S. agriculture most hybrid seed is developed and provided by private firms. However, these firms rely on publicly funded research for basic advances embodied in new inbred lines.

14. Ruttan, Binswanger and Hayami, 1977; Binswanger and Ruttan, 1977; deJanvry, 1977; Hayami, 1976.

At the micro level the induced innovation hypothesis has strong and clear implications for the allocation of research resources to factors of production but is less useful for commodity allocation of research resources. Factors of production which are primarily labour-saving have low pay-off in low wage environments and research on them will not result in a strong growth contribution unless they are introduced in an environment with rapidly rising wage rates. It is probably safe to classify production factor research into a group which is primarily yield-increasing (although minor labour-saving effects may also be present) and a group which is primarily labour-saving (although some minor yield effects may also be present). The yield-increasing group contains fertilizer and varietal research and the corresponding support sciences such as genetics physiology, pathology and physiology. It also includes research in other fields such as pesticide research, microbiology, soil fertility, soil and water management research including soil and water related mechanical devices. Most other mechanical inputs and herbicides belong to the labour-saving category.[15] In the next section we will show that distributional considerations strengthen the case for taking factor scarcities into account in research resource allocation. This is a case where efficiency and equity considerations are reinforcing each other rather than being in conflict.[16]

EQUITY GOALS AND RESEARCH RESOURCE ALLOCATION

Progress on the equity impact of technical change has been more limited than on the efficiency impact. We are not yet able to specify *ex ante* all the equity impacts. Different techniques of analysis may lead to contradictory predictions of distributional consequences.[17] And economists often do not agree on how to trade-off efficiency versus equity effects, if such trade-offs exist. In this section we want to briefly indicate a few generalizations which by now have solid theoretical support and/or where equity and efficiency

15. For a review of the impact of mechanization on labour demand, see Kaplana Bardhan, 1977. For a special review of tractors in the South Asian Sub-Continent, see Binswanger, 1977.

16. To demonstrate the low pay-off from essentially labour-saving research such as on herbicides in a low wage economy as India does not require sophisticated analytical tools. Binswanger and Shetty, 1977 tabulated data on the frequency of interculture and hand weeding operations in various crops of three agro-climatic areas of the Semi-Arid Tropics. They also computed the delays between sowing time and the first hand weeding and interculture operations. The results indicate that the farmer's allocation of weed control effort is quite rational. In environments where both crop and weed growth are vigorous and assured, farmers tend to do as many or more weed control operations on time as a weed scientist might recommend. In less prosperous environments and on very low value crops weed control effort is less but it has not yet been demonstrated that additional weed control efforts would have any economic pay-off. Diagnostic experiments are under way to test this.

A simple budget exercise further revealed that under the wage rate conditions of the semi-arid tropical areas considered, mechanical weed control efforts on rainfed crops are cheaper by more than 50 per cent than weed control plans using selective herbicide applications. Pure herbicide control is out of the question on cost grounds. It would have to be demonstrated that herbicide use leads to substantial yield increases relative to mechanical weed control efforts (not relative to unweeded conditions) before one could expect any growth contribution from herbicide research.

Finally, farm level data indicated that depending on the crop considered between 70 to 90 per cent of hand weeding is done by hired female labour. Herbicides would thus tend to reduce employment opportunities for the most disadvantaged social group in the rural areas, female landless labourers.

17. On the different predictions of partial versus general equilibrium analysis, see Binswanger, 1976.

goals do not conflict. We will contrast them with areas where no generalizations are yet possible, where difficult trade-offs between efficiency and equity exist or where welfare gains of one poor group may be in conflict with gains for other poor groups.

(1) The Distributional Effects among Producers of a Given Region

Distributional problems arise out of the adoption cycle, relative land and labour endowments, and the access to output, modern input and credit markets. It is clear that early adoption of a technology provides innovator's rents. As we shall see, innovator's rents are sometimes the only producer benefits from technical change in markets with inelastic final demand where widespread adoption ultimately leads to price reductions. How they are distributed is thus important, despite their transitory nature. It is clear that large producers will usually be among the early adopters since they have a much stronger incentive to search for information about new technology. The benefits from adoption are proportional to size while the costs are not, hence larger producers have a much stronger incentive to search than smaller ones (Welch, 1976).[18]

Innovator's rents are thus a pay-off to superior information searching and processing capacities, and also a necessary compensation for the risk of failure of new techniques borne by the early innovators who are providing imitators with cheaper and more reliable information. Too often research is concentrated on success stories which may lead to an over-estimation of these innovator's rents relative to the long-run situation which should embrace successes and failures.[19]

Nevertheless, the pay-offs are proportional to size. The adoption cycle thus leads to a regressive impact on the income distribution. This particular impact is transitory. It is also clear that every new technology is subject to such regressive adoption lags and agricultural researchers can do little about them.

The unequal distribution of land has several implications for research resource allocation. A straightforward one regards scale effects of technologies. Biological innovations are usually divisible and hence scale neutral. Scale economies arise with mechanical innovations and some soil and water management techniques. A strategy favouring small farmers should thus discourage research resource allocation to large-scale or expensive machines. In this context, little conflict between equity and efficiency should arise since most mechanical innovations are labour-saving and unlikely to result in large efficiency gains in low wage countries.[20]

18. The incentive for extension agents and input salesmen to work primarily with larger farmers also stems from the larger area adopted or amount of product sold per contact with larger farmers.

19. For example, early adopters of hybrid pearl millets which became susceptible to downy mildew probably suffered substantial losses before reverting back to traditional varieties.

20. Very efficient rental markets for machines could overcome the large farmer biases of such machines. In some areas such markets are, however, not well developed.

Apart from the unequal distribution in land ownership or operational holdings, there is the issue of the systematic positive correlation between land holding size and land-labour ratio (operational holding value divided by labour used, not owned). In one village of Mahboobnagar district in Andhra Pradesh, for example, the land-labour use ratio was 4.4, 6.8 and 7.9 for the small, the medium and the large holdings, respectively. Inter-group variability by far exceeded the variability among groups. Do these differences permit a conclusion analogous to the Hayami and Ruttan framework that two technologies need to be developed, a labour-using one for small farmers with lower land to labour ratio and a relatively labour-saving one for the larger groups with higher land-labour ratios. We believe that this is not the case. With the exception of their relative managerial skills, all farmers in principle have access to the same technologies so that it is unlikely that the factor ratio differences reflect different technologies available to them. The differences are probably caused by imperfection in the land, labour and capital markets leading to different implicit price ratios facing different farmers.[21] The large variation in factor use ratios across farm size-groups, and the even larger within-group variability, points to substantial and persistent factor market imperfections. Factor rental markets simply do not equalise factor ratios when factor endowment ratios vary substantially.

More efficient markets would tend to narrow down the factor use ratio differences. Therefore, on efficiency grounds we should argue for improvements in factor markets, not differential technologies. This would automatically remove the need for planning factor ratio differences in technologies. In the inter-country case considered by Hayami and Ruttan, opportunities for equalising factor ratios across countries do not exist, thus the emphasis is on adjusting the technology to the factor ratios.[22]

We must also ask whether the emphasis on yield-increasing against labour-using technical change for low wage countries implied in the Hayami-Ruttan approach is consistent with the goal of helping small farmers. In the two-factor models of distributional consequences of technical change both partial and general equilibrium approaches agree: land-saving or labour-using technical change tends to reduce the growth rate of land rents and increase the growth rate of wage rates (or opportunity costs of labour).[23] Since small farmers have a larger endowment of labour relative to land than large farmers, their relative income position will be better with labour-using than labour-saving technical change.

21. This assertion needs more empirical back up. But even if the differences were related to product mix differences in which small farmers specialise on labour intensive commodities, the cause would still be the differences in implicit factor prices.

22. Inter-country differences in land-labour ratios are also much larger than within-country differences. Unadjusted for land values the U.S. land-labour ratio exceeds the Japanese one by a factor of 100. Taking account of much larger investments in land improvements would bring this factor down to may be 15 to 30, whereas in India the inter-regional factor ratio differences across farm size-groups is probably much lower, but more empirical evidence is needed.

23. Evenson, 1976; Binswanger, 1976a.

The third determinant of the distributional impact of a technical change among producers is their relative access to product and modern input markets. If access to input and credit markets is unequal prior to the introduction of new technology, any innovation which leads to greater dependence on these markets will lead to a regressive distribution of the gains of modern input-using technical changes. This regressive impact is not transitory. To remedy the situation requires institutional changes which will equalise the access of producers to product and modern input markets. Blaming the regressive impact on the technology makes little sense unless clearly superior technologies can be developed which do not increase dependence on markets. In agriculture this is highly unlikely. It is interesting to note that the green revolution has led to a much greater realisation of the inequalities of access existing in these markets and to a substantial amount of policy to remedy it.

Taking account of distributional implications among farm size-groups in low wage countries thus reinforces the efficiency consideration of concentrating on labour-using and land-saving technical changes while at the same time calling for institutional changes to improve the efficiency of land and labour markets and the access of small farmers to modern input and credit markets. Furthermore, both negative effects of adoption lags and of unequal factor market access might be reduced by more emphasis on research and extension which allows a stepwise adoption of technology. This has been discussed more fully by Ryan and Subrahmanyam (1975). It is well-known that farmers very rarely adopt entire recommended technology packages initially and even in the long-run adoption of packages often remains partial (Perrin and Winkelmann, 1976). A systematic research approach to identify in advance which of the elements of a package have very high pay-offs and/or very low cash input intensity coupled with corresponding extension efforts can help reduce the regressive impact of long adoption cycles and unequal access to modern inputs and credit.

(2) *Producers versus Consumers*

The conflict about the distribution of gains between agricultural producers and consumers has been the major distributional conflict in Europe and North America. It is usually analysed in comparative static partial equilibrium models. The basic conclusion of these consumer-producer surplus models is that under perfectly elastic commodity demand producers capture all the gains, whereas under very inelastic demand consumers gain disproportionately at the expense of real losses to producers. The total gain is captured by consumers, with producers neither gaining nor losing when the elasticity of final demand is equal to minus 1.

Furthermore, it is clear that, whenever gains are captured by consumers the impact of most technical changes in food production on income distribution is progressive.[24] Poor people spend a large proportion of their budget on food and the proportional gain in their real income (deflated by a price index using their own consumption weights) is larger than that of rich people who spend proportionately less on food. Furthermore, the lower the income and price elasticity of particular foods, the larger their budget shares among the poorest consumers. Research resource allocations designed to help the poorest consumers should thus stress commodities with low income and price elasticities. This point has been substantially elaborated by Per Pinstrup-Andersen, *et al.* and by Ryan (1977 a,b).[25] Such a strategy would also benefit small subsistence producers relative to large commercial farmers since the former stand to gain relatively more as consumers if prices drop as a consequence of technical change.[26]

However, both Mellor (1977) and deCastro and Schuh (1977) point to a possible conflict apparent in partial equilibrium models: Technical change in commodities with inelastic demand lead to a reduction in demand for factors of production since the saving in factors of production made possible by the technical change is not outweighed by the increase in final demand caused by the price fall. Thus technical change in these commodities lead to reductions in producers' incomes and in labour demand. However, the partial equilibrium models neglect the income effects resulting from the price reductions of these food items. If the additional real income is spent on labour intensive commodities, the employment loss in the commodities which experience technical change can be offset by employment gains elsewhere. The Mellor and deCastro and Schuh conclusions need to be discounted.[27] In the area of commodity allocation of research resources general equilibrium models can thus contradict partial equilibrium ones (Binswanger, 1976a).

Nevertheless, if for a country or a region the objective of policy is to maximize producer income and/or agricultural employment, research resources could be concentrated on commodities with high price elasticities. Export commodities have the highest such elasticities. The possible conflict between lowering prices to domestic consumers and increasing employment has to be acknowledged in research resource allocation decisions to commodities.

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24. Exceptions to this are technical changes which are confined to luxury foods.

25. Per Pinstrup-Andersen, *et al.*, use a full system of income and price elasticities by income groups to evaluate the impact of supply curve shifts of individual agricultural commodities on the nutrition levels of households in Cali, Columbia. They conclude that changes in total availability of nutrients may be a poor indicator of changes in consumption of nutrients by income groups. Ryan, *et al.*, have examined the existing nutritional status of people living in the semi-arid tropics and used evidence from genetic trade-offs and partial equilibrium analysis to demonstrate the superiority of yield oriented crop breeding strategies in attaining nutritional improvements compared with strategies which emphasize cryptic grain quality improvements.

26. Hayami and Herdt, 1976.

27. Of course, the additional people employed in other commodities may not be the same as those replaced by the technical change since additional employment could be generated in industry, for example.

(3) Landowners versus Labourers

The clearest conclusion which distributional analysis has to offer relates to factoral allocation. It has already been mentioned that regardless of analytical technique used, labour-saving technical change retards growth of wage rates and employment. Therefore, in countries with low and/or stagnant wages this type of research should be discouraged on efficiency and equity grounds.

What is more puzzling is the distributional impact of neutral technical changes such as the green revolution. It has been observed from micro-studies that in those areas experiencing the technical change, land rents have been rising faster than wage rates (Hanumantha Rao, 1975; Deepak Lal, 1976). Partial equilibrium analysis has a simple explanation for this. The regions experiencing technical changes were faced with elastic final demand because they supplied a national market in which other regions were not substantially expanding supplies. The technical change reduced demand for factors per unit of output, but the expansion in production was more than enough to offset the initial reduction and the demand curves for all factors of production shifted to the right. This led to *large price rises for the factors in relatively inelastic supply* and only modest increases for those in relatively elastic supply. Thus land rents rose rapidly while the gains of labour were curtailed by elastic supply of labour from other regions or States. Again it was not technology, but the factor and product market conditions which determined the distributional outcome.

Research and researchers can do little about factor market conditions which distribute gains in favour of landowners. If the same technical changes which seem to have favoured landowners had been more widespread over India than they were, the distributional outcome would have been different because producers would not have faced such an elastic product demand nor such an elastic labour supply. Since market conditions and the geographic scope of introduction of a technology influence distributional outcomes it becomes extremly difficult to predict the distributional outcome for factors of production of any individual technical change in advance. Not only does one need to know the nature of the technical change but also where it will be adopted and in which sequence. If general equilibrium effects are taken into account the analysis becomes even more complex. Economists can offer little guidance to the research administrator except recommending that labour-saving technical change always adversely affects labour.

(4) Distributional Consequences among Regions[28]

In agriculture in particular, but also in other industries, technical change is often confined to certain regions because of environmental or economic

28. This section follows closely Evenson, 1976.

location specificity. In particular, the green revolution has been confined largely to irrigated zones with good water control. Partial equilibrium analysis of the distributional consequences of this unequal regional access is again straightforward and it is unlikely that general equilibrium analysis would change it. If two regions supply the same national market, then each region may face elastic commodity demand even if the national demand is inelastic. Thus producers in the region experiencing technical change gain absolutely. Nevertheless, national price levels will fall although not necessarily by much. Thus producers in the region without access to the technology lose absolutely and relative to the gaining regions since they face reduced prices without a concomitant cost reduction.

We already know how the benefits in the gaining region will be distributed among landowners and workers. In the losing region the *largest share of the losses will be borne by the factors in most inelastic supply*, or in other words, by the immobile factors of production. Land prices will decline more, rise less rapidly than wage rates because some labour will migrate to the gaining region (and contain the wage rate rise there). Note that this model accords well with what is known about regional wage rate changes in India since 1965.

This impact of the green revolution on regional income distribution has probably been more important than any other distributional impact. It also has been regressive since the green revolution was largely confined to already more prosperous areas.[29] The regional impact is also particularly straightforward to analyse and can more easily be integrated into a research resource allocation decision than distributional issues among factors of production.

CONCLUSIONS

Economic analysis has contributed substantially to a better understanding of the factors governing efficiency of research resource allocation, both at the micro and macro levels. It appears that economists can play an useful role in the process of identifying constraints limiting production and suggesting research or institutional and policy measures to break them. Much of this work can be done with standard tools, a good and continuously up-to-date micro level data base and access to secondary statistics.[30]

On the welfare and equity side progress has also been made. Equity impacts of scale and factor-saving biases are readily apparent and straightforward to take into account. Regional effects are also clear. More complicated are distributional effects where the outcomes depend on output and factor market conditions. Among these the distributional issues between

29. See Binswanger and Ruttan 1977, Chapter 13.
30. This is also an area which lends itself well to multi-disciplinary co-operation although, at the research institute level it requires substantial amounts of patience and persistence.

producers and consumers or between foreign and domestic consumers are the most transparent ones. Approaches have been developed to study the distributional impacts among consumer groups with different income levels. Most troublesome are functional income distribution issues among landowners and labourers. A complicated interplay across markets for different commodities, land and labour prevent easy generalizations except that in all cases labour-saving technical change adversely affects labour. On this issue, further progress is necessary before economics can give clear guidance to the research administrator.

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