INCOME REDISTRIBUTION AND THE VALUE OF FORESTRY RESEARCH: ISSUES AND APPROACHES[1]

by

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May 1984

Staff Paper Series Number 41

[1]Research supported by the Department of Forest Resources, the Agricultural Experiment Station, University of Minnesota, and the U.S. Department of Agriculture, Forest Service. Published as Paper No. 13,979 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station.

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Income Redistribution and the Value of Forestry Research: Issues and Approaches

Investment in research and development has been widely recognized as having a significant impact on economic efficiency (Evenson, et al., 1979). Technological change resulting from a successful research effort enables less expensive or relatively abundant resources to be substituted for expensive or scarce resources. But research also entails distributional consequences -- some groups within society will be made better off as a result of a particular research effort, while others could be made worse off.

The income redistribution effects of research have received little attention from research evaluators, however, despite the fact that policymakers are likely to be interested in these issues (Gregersen and McGaughey, 1984). Most research evaluations have either ignored questions relating to income distribution or else simply examined the distribution of gross research benefits between all consumers and all producers. From a public policy standpoint, it would be desirable to have a more detailed breakdown of distributional impacts. Thus, focusing attention on economic efficiency in the evaluation of research and giving scant attention to equity issues has limited the potential usefulness of evaluation results.

This paper will discuss some of the issues involved in including an examination of distributional effects in evaluating forestry research. Since forestry research evaluation is a nascent area of inquiry, this review should be useful to researchers in this area as source of reference. The approach has been to outline major distributional issues relevant to research evaluation, discuss important factors and empirical findings relating to each issue, and cite a liberal number of references from the literature for those interested in digging deeper into specific areas. Four distributional issues are considered:

1. the distribution of gross research benefits between producers and consumers;
2. the impact of research on the functional distribution of income;
3. the distribution of net benefits among households and among producers;
4. distributional impacts among geographic regions.

The first three issues were identified by Scobie and Posada (1978) as having been investigated to a limited extent by agricultural economists, and Binswanger (1980b) suggested the fourth issue. Intertemporal income distribution impacts of research are not considered here, although this would be an interesting area for future work: the long growing period of many tree species suggests that future generations will benefit from biological forestry research, while the present generation will benefit from utilization research.

A comparative static partial equilibrium framework has been adopted to illustrate each of the above issues. Using this approach, an analysis of income distribution effects may be included in consumer-producer surplus evaluations of forestry research without greatly increasing data requirements. Consumer-producer surplus models have been used extensively to evaluate economic efficiency impacts of research. This evaluation approach is likely to find widespread application in forestry because of its flexibility and relatively low demands for data.[2] General equilibrium models have also been developed to analyze the distributional effects of agricultural research (Binswanger, 1980a), but heavy data requirements are likely to limit the applicability of these models, particularly in forestry.

One caveat is in order before proceeding. It has been assumed throughout that equal welfare weights are attached to each sector, factor of production and income group in assessing the distributional effects of research and technological change. This is a critical assumption, and one that is pervasive in the literature. It is also a rather arbitrary assumption, since "attaching unequal welfare weights to different social groups requires no more of a value judgement than attaching equal welfare weights," (Bieri, et al., 1972, p. 803). Very little work has been done on the distributional effects of research where different groups in society receive unequal welfare weights. Clearly, the implications for research policy could vary considerably when different sets of welfare weights are used.

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[2]See Schuh and Tollini (1979), Norton and Davis (1981) and Seldon (1983) for discussions of consumer-producer surplus research evaluation models and comparisons with other evaluation methods.

1. Distribution of Gross Research Benefits Between Consumers and Producers

A number of agricultural research evaluations have examined the gross benefits captured by consumers and by producers.[3] Using the basic consumer and producer framework, it is possible to determine the distribution of gross benefits between these two groups without any additional data beyond that which is required to compute total economic surplus. Figure 1 illustrates the conceptual framework for this analysis. The basic idea is that research on a given commodity or service will lower its marginal cost of production. This is represented graphically by a downward shift in the supply curve. Assuming market equilibrium and no trade of the commodity in question, the shift in supply from S_0 to S_1 increases consumer surplus by the area P_0ABP_1. Producer surplus is changed by the area OCB minus P_0ACP_1, and the total change in social benefit is represented by the area OAB. Many different formulas have been used in empirical studies to calculate these areas, mainly because different assumptions are made about the nature of the shift in the supply curve due to research. Scobie (1976) and Jarrett and Lindner (1977) discuss alternative formulas and the lack of consistency between studies.

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[3]For examples of research evaluations that have included this type of analysis, see Ayer and Schuh (1972), Akino and Hayami (1975) and Nagy and Furtan (1978).

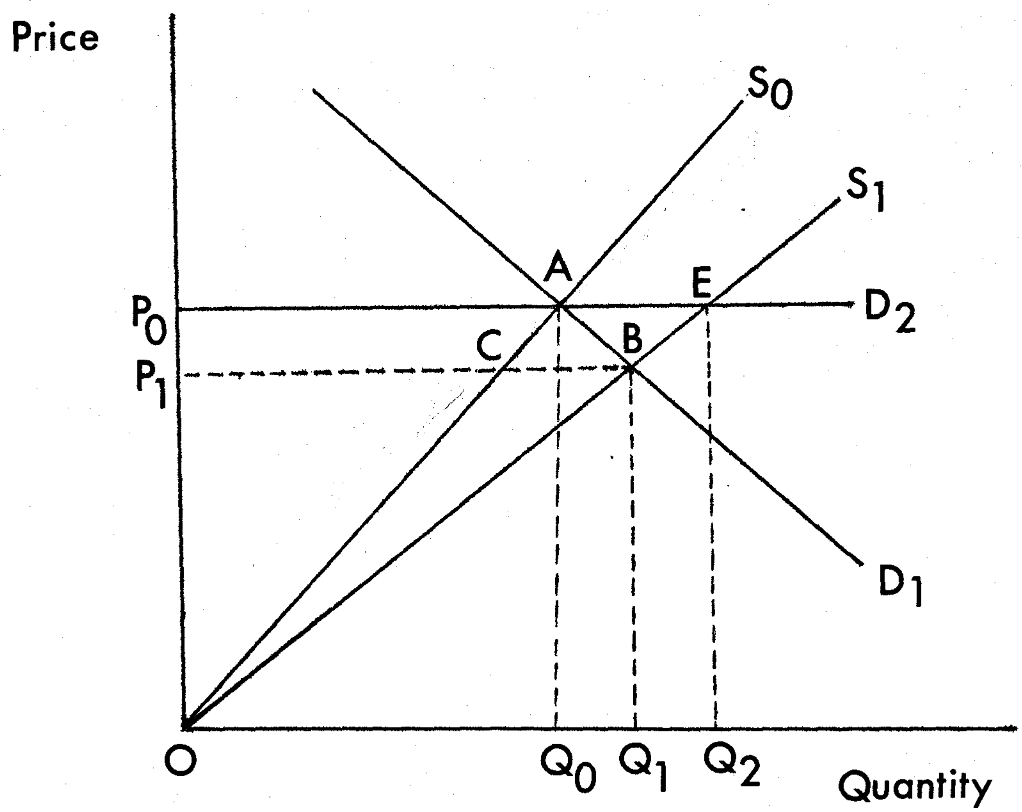

Figure 1. Basic framework for the analysis of consumer and producer surplus.

Distribution of gross research benefits between producers and consumers is determined by two main factors: the price elasticities of supply and demand for the commodity, and the type of supply shift resulting from research.[4] This assumes market equilibrium. If government pricing policies favor either consumers or producers, this will clearly be another determinant of the distribution of research benefits. The following paragraphs explore in detail the two main determinants of the distribution of gains between producers and consumers.

1.1 Elasticities of Supply and Demand

The elasticities of supply and demand for a commodity that has been the focus of research to improve production efficiency are particularly important determinants of the distribution of research benefits. Beginning with the elasticity of demand, when commodity demand is perfectly elastic producers capture all the gains from technological change. This is shown in Figure 1. With a perfectly elastic demand (D_2), the supply shift induced by research increases producer surplus from P_0AO to P_0EO and consumer surplus is unchanged.

When demand is inelastic (D_1 in Figure 1), consumers will benefit and producers surplus could increase, remain the same, or decrease

[4]The relative rates at which the supply and demand curves are shifting over time is also a factor. Producers will benefit most from research on commodities for which demand is growing more rapidly than supply, while consumers will be better off if research is carried out on goods with slow growth in demand relative to supply.

depending on whether the area OCB (a gain to producers) is greater than, equal to, or less than the area P_0ACP_1 (a loss to producers). All other things being equal, consumer surplus will be greater when demand is relatively inelastic and producer surplus will be greater when demand is more elastic.

The price elasticity of supply is also an important determinant of the distribution of research benefits. Table 1 illustrates the effects of elasticities on consumer and producer surplus for a constant shift in the supply curve. The examples of cotton (a commodity with export potential) and manioc (a subsistence crop) show the widely divergent distributional consequences resulting from research on commodities with different elasticities. As shown in Table 1, producers benefit most from research on commodities with relatively low supply elasticities and high demand elasticities such as cotton. Consumers, on the other hand, will benefit more from research on commodities with highly elastic supply and low demand elasticity such as manioc. It is important to note that it is the relative magnitude of the elasticities that matters. Ramalho de Castro and Schuh (1977, p. 508) state that "If the supply elasticity were larger than the demand elasticity, regardless of the absolute size of the demand elasticity, the consumer would tend to receive a larger share of the benefits."

Table 1. Percent of benefits to consumers and producers resulting from a specified shift in the supply curve, based on two demand and three supply elasticities, Brazil.[a]

Crop	Demand Elasticity	Percent of Benefits[b]					
		consumer	producer	consumer	producer	consumer	producer
		(.19)		(.94)		(1.57)	
Cotton	-2.00	9	91	32	68	42	58
	-5.30	4	96	15	85	23	77
		(.11)		(.47)		(.96)	
Manioc	- .10	52	48	82	18	91	9
	- .30	27	73	61	39	76	24

[a] Source: Ramalho de Castro and Schuh, 1977, p. 508.
[b] Supply elasticities are given in parenthesis.

Several implications for research policy can be drawn from the above discussion. Hertford and Schmitz (1977) note that consumers will benefit most from research on goods with highly inelastic demands, and suggest an implication for research in developing nations:

> Such results support the notion that research on basic subsistence commodities would particularly benefit consumers, while research on more price elastic commodities -- for example, rubber, cotton, and perhaps coffee -- would be especially remunerative for producers, input owners, and certain factors of production (pp. 155-6).

Therefore, in forestry, research on commodities such as fuelwood in developing nations will have a progressive impact on income distribution; low income groups spend a higher proportion of their budget on fuelwood than high income groups, and they would experience a larger proportional gain in real income. Similarly, research on luxury commodities (such as paper products in many LDC's) would have a regressive income distribution effect.

Another implication for research policy that can be drawn from the information presented in Table 1 is that research aimed at increasing the elasticity of supply would increase the consumer's share of benefits even on commodities with high price elasticities of demand. For example, this might be accomplished by tree breeding programs which would increase the viability of a certain species in different geographical areas and growing environments.

1.2 Nature of the Supply Shift

The nature of the shift in the supply curve induced by research is also a determinant of the distribution of gross research benefits between producers and consumers. Three types of supply shifts will be considered here:[5]

1. Divergent (in which costs at the margin are reduced more than infra-marginal costs);
2. Parallel (in which marginal production costs are reduced by the same amount for marginal and infra-marginal units);
3. Convergent (in which marginal production costs fall by less than in infra-marginal costs).

Figure 2 illustrates these three possibilities. Duncan and Tisdell (1971) have stated three propositions that relate the nature of the supply shift and the price elasticity of demand to the distribution of research benefits. Proposition one states that "If the demand curve for

[5]Lindner and Jarrett (1978) analyze two types of divergent shifts: divergent pivotal and proportional. Only the former type is considered here to simplify the exposition.

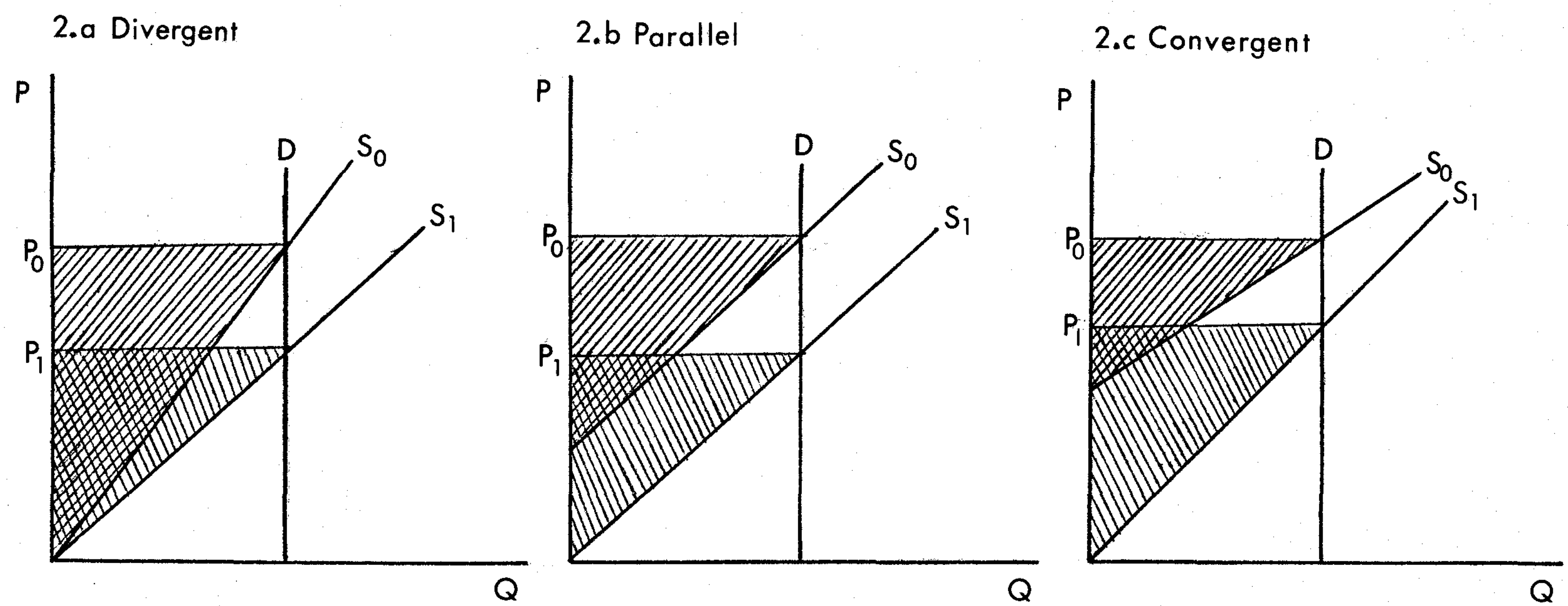

Figure 2. Distribution of research benefits and the nature of the supply shift.

the product is perfectly elastic, technical progress that leads to any shift downward in the supply curve always increases the industry's surplus," (p. 127). This is simply a broader statement of one of the results from the previous section.

Proposition two states that when demand is perfectly inelastic:

1. Producer surplus will decrease (and consumer surplus increase) if the supply shift is divergent;

2. Producer surplus will be unchanged (and consumer surplus increase) if the supply shift is parallel;

3. Producer surplus will increase (and consumer surplus will increase, but relatively less than in the previous two cases) if the supply shift is convergent.

These three results are shown with respect to producer surplus in Figures 2.a, 2.b and 2.c, respectively. In each case, the top shaded area represents total producer surplus before research, and the bottom shaded area is the producer surplus resulting from a divergent, parallel or convergent shift in supply. Comparison of the areas of the triangles before and after the supply shifts confirms this proposition.

Finally, Duncan and Tisdell's third proportion states that when the price elasticity of demand is intermediate, a supply shift may reduce producer surplus, "and is more likely to do so (a) the greater is the reduction in cost of producing marginal units as compared with infra-marginal ones, and (b) the more inelastic is the demand curve. The converse also holds," (p. 128). In other words, the more divergent the supply shift and inelastic the demand, the more likely producers are to lose as a result of technological innovation. Analogously, consumer surplus will be greater when (a) the supply shift is more divergent, and (b) the demand curve is more inelastic.

Some discussion has been generated about the type of supply shift that may be induced by different types of research in agriculture. Lindner and Jarrett (1978) have argued that biological and chemical innovations will tend to produce divergent supply shifts, and that mechanical and organizational innovations will result in convergent shifts. Two reasons are given in support of these assertaions. First, Lindner and Jarrett argue that if a biological innovation is evenly diffused, it will typically lower the per unit production costs of marginal producers more than infra-marginal producers, resulting in a divergent supply shift.

Second, the adoption of many mechanical and organizational innovations is often scale dependent. If large scale, low cost producers are more likely to adopt an innovation, then the resulting supply shift will be convergent. As a word of caution, however, it should be noted that before making these generalizations, Lindner and Jarrett comment on "the impossibility of making unqualified a priori generalizations about the nature of the shift in the supply curve," (p. 55).

If these generalizations are correct, the implication for public research policy is that the government should concentrate on funding biological and chemical research in order to benefit consumers to the largest extent: a divergent supply shift will favor this group, assuming that demand is not perfectly elastic. Marginal producers will also be likely to gain relative to infra-marginal firms as a result of this type of research.

2. Impact of Research on the Functional Distribution of Income

Examining the distribution of gross research benefits between producers and consumers is only a first step in analyzing the distributional impacts of research. Another important question is the effect of research and technical change on the functional distribution of income, defined as the income shares accruing to the owners of property (or capital) and the earnings of labor. In other words, how are producer benefits distributed among the factors of production? For examples of agricultural research evaluations that have included this type of analysis, see Walace and Hoover (1966), Ayer and Schuh (1972) and Araji and Sparks (1975).

Three main determinants of the functional distribution of income will be considered: the elasticity of input supply, the elasticity of final product demand and whether technical change is neutral or biased.[6]

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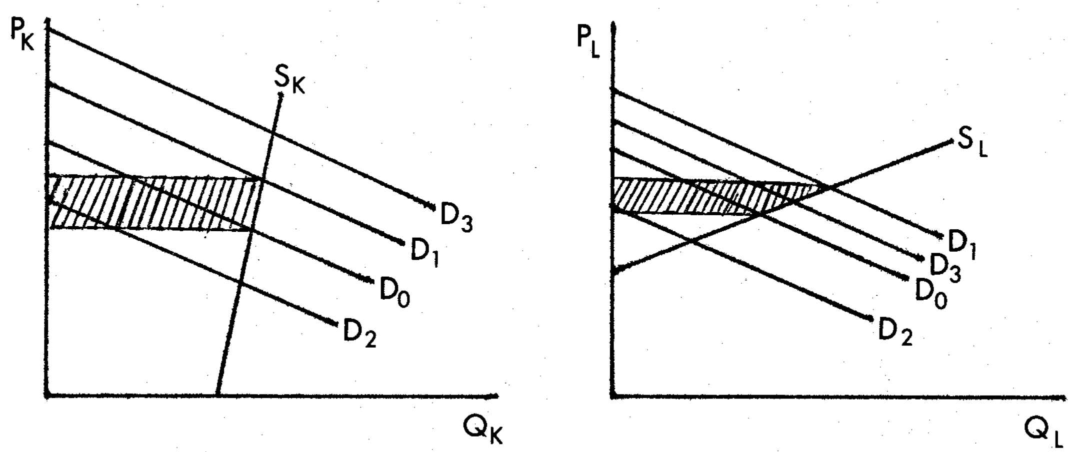
[6]Hicks neutral technical change leaves the marginal rate of substitution between factors unaffected. Thus, for a given ratio of factor prices, factor proportions remain unchanged. Non-neutral or biased technical change is generally described as either labor-saving or capital-saving. Technical change is labor-saving if the marginal productivity of capital increases relative to that of labor. See Peterson and Hayami (1977) for a discussion, and Brown (1966) for a detailed discussion.

2.1 Elasticity of Input Supply

Figure 3 depicts the impacts of technical change on two factor markets and the corresponding product market. In the diagram, capital is shown to be inelasticly supplied while the supply of labor is more elastic. Given neutral technical change and an elastic demand in the product market (D_1), the equilibrium level of output will increase. This will lead to a rightward shift in the two factor demand curves, from D_0 to D_1 in each case. Since neutral technical change is assumed, the demand for labor will shift out by the same percentage as the demand for capital. Notice that the increase in the capital rental rate (P_k) will be much greater than the increase in the labor wage (P_1). Therefore, the price of the more inelastically supplied factor will increase relative to the price of the other factor.

However, the increased payments to capital in this case (shown by shaded area in the capital market) may or may not outweigh the increased payments to labor (shown by the shaded area in the labor market). If the higher quantity of labor demanded is sufficiently large, the increased payments to labor could be greater than those to capital. Binswanger (1980b) notes that the total increase in the wage bill of a particular sector is typically not a net gain to society. If the additional workers are drawn from other sectors, their opportunity wage must be subtracted from the increase in payments to labor to obtain the net gain.

Factor Markets



Product Market

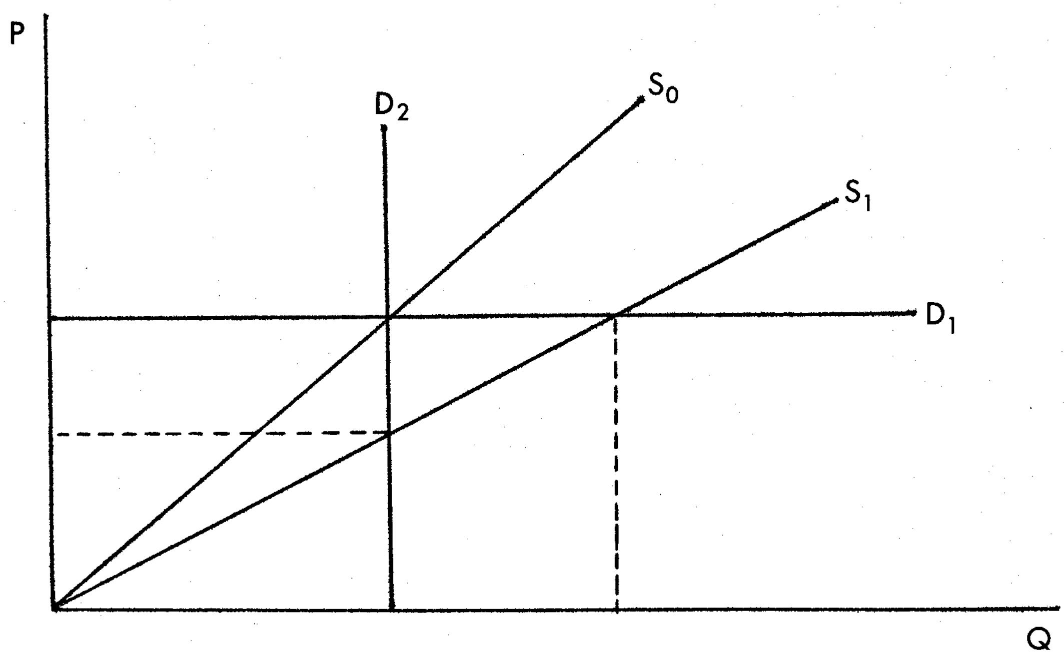


Figure 3. The functional distribution of research benefits.

An interesting example of how this type of analysis may be easily included in a research evaluation is given by Ayer and Schuh (1972). In an evaluation of cotton research in Brazil, they included a qualitative analysis of the distribution of producer benefits among the factors of production. It was argued that "The effect of the shift in demand for inputs on factor returns and resource utilization, then, depends on the relative elasticities of supply of the inputs," (p. 565). As shown in the above discussion, this will be true if technical change is neutral and the demand for the final product is elastic, the latter assumption being entirely plausible for cotton in Brazil.

Ayer and Schuh examined three factors: land, entrepreneurial talent and labor. The supply elasticities of land and entrepreneurial talent for cotton production in Brazil are believed to be relatively inelastic, so it was hypothesized that a significant share of producer benefits will be captured by the owners of these factors. Landowners receive benefits in the form of higher land values, and the possessors of entrepreneurial abilities receive an economic rent in the form of higher income.

The supply of labor in Brazil, on the other hand, is likely to be quite elastic. Ayer and Schuh therefore hypothesized that the adoption of new technology for cotton production did not result in higher real wages, although the level of employment did increase. Data on wages of cotton workers and employment levels in Sao Paulo tend to support this hypothesis, according to Ayer and Schuh.

2.2 Elasticity of Final Product Demand

Another factor to consider in analyzing the functional distribution of research benefits is the elasticity of product demand. In the preceeding section, product demand was assumed to be elastic. Technical change in this case was shown to increase the equilibrium level of output, and hence outward shifts in the input demand curves result. If instead the product demand is perfectly inelastic (D_2 in Figure 3), technical change will not increase the equilibrium output, and factor demand curves will shift backwards. This is due to the resource savings at a given level of output made possible by technical change. The backward shifts in factor demand are illustrated in Figure 3 by the D_2 demand curves in the capital and labor markets, where D_0 is once again the initial factor demand in each market. These shifts will be equiproportional when technical change is neutral, as before.

Two conclusions follow from this consideration of final product demand elasticity. First, all factors of production are net losers as a result of technical change when product demand is perfectly inelastic. This is, of course, consistent with earlier conclusions: total producer surplus declines with technical change when demand is inelastic. Second, the factor of production that is more inelastically supplied will experience a larger reduction in price. In Figure 3 it is clear that when factor demands shift back from D_0 to D_2, the price of capital declines more than the wage of labor.

2.3 Biased Technical Change

The preceeding two sections have assumed neutral technical change. If instead technical change is biased towards one factor, then the resulting shifts in factor demand will no longer be equiproportional. This is illustrated in Figure 3 for labor-saving technical change. Given an elastic demand in the product market (D_1), a labor-saving technical change will produce a larger outward shift in the demand for capital relative to the increased demand for labor. This is shown by the demand shifts in the respective factor markets from D_0 to D_3. Notice that the price of capital will rise even more relative to the wage of labor than in the case of neutral technical change. Total payments to labor will also be lower when technical change is labor-saving than would be the case for capital-saving or neutral change. Clearly, biased technical change will favor the owners of inputs whose marginal productivity is enhanced the most by research.

There has been extensive discussion of the effects of agricultural research couched in the Hicksian classification of technical change. The concensus has been that mechanical innovations are basically labor-saving and that biological and chemical innovations are land-saving. For examples of this type of discussion, see Heady (1949), Hayami and Ruttan (1971) and Bieri, DeJanvry and Schmitz (1972).

Technical change in the lumber and wood products industry has been found to be labor-saving (Stier, 1980; Greber and White, 1982). An analysis of the impacts of new technologies on the labor force would, therefore, be of interest in a research evaluation in this industry.

For example, structural particleboard is a labor-saving wood-based panel innovation that is rapidly substituting for plywood in many applications (Bengston, 1983). A typical structural particleboard plant requires less than half the labor input of a plywood plant of the same capacity. It would be interesting to examine the functional distribution of income in this case, and to explore a related welfare question: the effects of compensating displaced workers in the plywood industry on the calculated rate of return to structural particleboard research.

Schmitz and Seckler (1970) have provided an example of how this might be done. In an evaluation of research leading to the development of the mechanized tomato harvester, they invoked the Hicks-Kaldor compensation test to assess in a limited way the welfare effects of this labor-saving innovation: "In order to determine the value of the harvestor, we have to determine whether the gainers (producers, consumers, etc.) could compensate the losers (workers) and still be better off than before," (p. 574).

Using data on the number of displaced man-hours per acre, wage rates, acreage and adoption rates, Schmitz and Seckler recalculated the rate of return to the tomato harvester research program. Different assumptions were made about the cost savings of mechanical harvesting and the proportion of the displaced wage bill that would be paid in compensation. Table 2 summarizes their findings. Investment in this line of research was found to be very attractive except when the lower cost savings are assumed and 100 percent of the displaced wage bill is compensated. Full compensation assumes that there are no employment alternatives for the displaced tomato pickers, which is unlikely.

Table 2. Net rates of social return to R&D on the tomato harvester.[a]

Percent of displaced wage bill paid compensation	Net rate of social return to R&D — Estimated cost savings at $5.47 per ton	Net rate of social return to R&D — Estimated cost savings at $7.51 per ton
	percent	
0	929	1,288
25	694	1,048
50	460	814
75	226	579
100	-8	345

[a] Source: Schmitz and Seckler 1970, p. 574.

3. Distribution of Net Benefits Among Producers and Among Consumers.

The preceeding two sections have looked at several aspects of analyzing the distributional consequences of research at a fairly high level of aggregation. But in order to be most useful to policymakers, a research evaluation should ideally include a more detailed breakdown of distributional effects among groups of consumers or producers (e.g., the distribution of net research benefits between consumers in different income strata, or between producers with different scales of operation). This section will examine these issues, beginning with three determinants of the distribution of the benefits of technical change among producers outlined by Binswanger (1980a). Examples of research evaluations that have included this type of analysis are rather limited. Two empirical studies that analyzed the distributional effects of research in detail will be reviewed to illustrate the issues and methodology involved.

3.1 Innovator's Rents, Scale Bias, and Access to Markets

The first determinant of the distribution of benefits among producers is the effect of early adoption of innovations. Early adopters will reap innovator's rents, which may be the only producer benefits if the demand for the commodity involved is very inelastic and adoption of the innovation is widespread. Large producers are usually among the early adopters because they have the greatest incentive to search for and adopt new techniques. Binswanger, therefore, claims that the technology adoption cycle leads to a temporary regressive effect on income distribution among producers.

Binswanger's second determinant is the effect of scale bias in technology. A technology is scale biased if it reduces the costs of large firms relatively more than small firms. An example would be tractors in many LDCs -- fairly large, contiguous fields are required to use tractors efficiently, which typically rules out adoption by low income farmers with small holdings. The benefits of scale biased technical change accrue mainly to large, wealthy firms and possibly not at all to small producers, so the impact on income distribution is permanent and regressive.

Finally, the relative access of producers to product and factor markets is another determinant. If access to input and credit markets, for example, is unequal prior to an innovation, and the innovation leads to greater dependence on these markets, then it will have a permanent regressive impact. The Green Revolution is often cited as an example of technical change having this effect, unless it is remedied by institutional change to equalize access to markets.

The importance of these factors in determining the distribution of research benefits among producers can be seen in the forest products industry. Large forest product firms are more likely to have research staffs capable of keeping abreast with new technologies developed through public sector research. Small firms typically lack the scientific and technical resources to do so. The large firms would therefore be expected to reap innovator's rents from forest products innovations.

This assumes that greater knowledge about an innovation leads to earlier adoption, a proposition that has generally been confirmed by research on the diffusion of innovations (Rogers and Shoemaker, 1971, p. 374-5). If large forest products firms do reap innovator's rents, this is an argument in favor of formal technology transfer efforts to provide technical assistance to small producers and ameliorate the regressive income distribution effects.

3.2 Two Empirical Studies

Hayami and Herdt (1977) examined the distribution of economic gains from technical change between consumers and producers when the commodity in question is partly consumed by semi-subsistence farmers. In this case, the distribution of research benefits was found to depend on the proportion of the crop marketed as well as the elasticities of supply and demand and the nature of the supply curve shift. In addition, they analyzed the differential benefits between large and small producers resulting from differences in adoption rates and marketable surplus. It was discovered that small producers benefit as much or more than large ones if the supply curve shifts faster than demand. A concluding recommendation was that R&D on major subsistence crops be increased in order to profit low income consumers and small producers.

Probably the most detailed breakdown of the distributional effects of agricultural research was carried out by Scobie and Posada (1978). They evaluated a rice breeding research program in Columbia that was specifically oriented towards the irrigated rice sector. After estimating the gross benefits accruing to consumers and two types of producers (upland and irrigated), they continued the distributional analysis by making two extensions.

First, the incidence of research costs was examined and the net benefits to producers and consumers derived. Costs borne by irrigated and upland producers and by consumers were identified and deducted from the gross research benefits of each group. Costs that were paid out of general tax revenue were divided between producers and consumers on the basis of the proportions of total taxes paid by urban and rural dwellers in 1970. Costs that were paid by producers ($(Col.) 0.01/kg. of rice from all growers to support research and extension) were broken down according to the quantity marketed by each type of producer in 1970.

It was discovered that net benefits were close to gross benefits for each group. Consumers gained as a result of the rice research effort because of lower prices and increased quantities marketed, while both upland and irrigated producers were net losers. The extent to which farmers benefited as rice consumers was not considered.

Next, Scobie and Posada examined the distribution of net benefits by income level: "To evaluate the distributional impacts of the technological change, the gross benefits, the costs of the research program, and the consequent net benefits were distributed across income groups for consumers and upland and irrigated producers" (p. 88). Ten income strata were identified for consumers, and it was assumed that gross benefits were directly proportional to rice consumption. Costs of research program borne by each income group of consumers were computed using data on the tax receipts from each income level.

It was found that net research benefits were captured largely by the poorest consumers. This would have been anticipated since rice is the main staple of the Columbian diet and is consumed disproportionately by lower income groups. The strength of the bias towards low income groups is indicated by the fact that "the lower 50% of Columbian households received about 15% of household income, (but) they captured nearly 70% of the net benefits of the research program" (pp. 88-89). Table 3 summarizes the results of this part of the analysis.

Table 3. Distribution of net benefits among consumers by income level.[a]

1970 Income Level	Annual Average Net Benefits	Net Benefits as a Percentage of Income
$(Col.)000	$(Col.)	
0-6	385	12.8
6-12	642	7.1
12-18	530	3.5
18-24	333	1.6
24-30	348	1.3
30-36	353	1.2
36-48	342	0.8
48-60	200	0.4
60-72	128	0.2
72+	138	0.2

[a] Source: Scobie and Posada 1978, p. 89.

Scobie and Posada's analysis of the distribution of producer surplus by income level and type of producer was flawed due to a lack of data. Specifically, data on the average net income by farm size for upland and irrigated rice producers was not available. In lieu of this information, they resorted to data on the distribution of average net income by farm size for the entire rural sector. The extent to which this data problem might have biased the results is unknown.

It was found that the low-income upland producers were most adversely affected by the research program. This is not a surprising result in light of the fact that the breeding program was completely oriented towards irrigated rice production. Upland farmers paid for some of the costs of research and reaped none of the ameliorating impact of increased production. They did benefit as rice consumers, but "Even if the average annual consumer benefits are included as benefits to upland producers, the small upland producers still appear as the most severely affected" (p. 90).

In forestry, the distribution of research benefits among different consumer groups is especially important in the context of developing nations. Low income consumers in many third world countries spend a disproportionate amount of their incomes on wood products for housing and fuelwood, and therefore will benefit the most from research on these necessities. In developed countries consumers spend a relatively small percentage of their incomes on wood products, but the demand for recreation services is fairly high among some groups. If upper income consumers spend disproportionately more on forest recreation, then recreation research could have a regressive effect on the personal distribution of income. See Gregory (1972, pp. 466-67) for a discussion of the income distribution effects of forest recreation.

4. Distributional Impacts Between Geographic Regions

Finally, since the adoption of some technological innovations is limited to certain geographic areas -- particularly in agriculture and forestry -- the distribution of research benefits between regions is of interest. This issue has been addressed conceptually by Evenson (1976) and Binswanger (1980b), and this section follows their discussions.

Figure 4 illustrates the simple case of 2 regions which supply some commodity to a national market. The aggregate demand is represented by D, the supply curve for region 1 is S_1, and the aggregate supply is $S_1 + S_2$, the horizontal sum of the amount supplied by each region at each price level. P is the equilibrium price before technical change, Q_1 is the amount supplied by region 1, and Q is the total quantity supplied nationally.

Suppose a technical change occurs in region 2 that is not applicable to region 1. This might be due to environmental specificity of the innovation or economic location specificity. The technical change will cause the supply in region 1 to shift out, resulting in a new total supply $S_1 + S'_2$, with the new equilibrium price P' and quantity Q'. The effects of this change on region 1 are a reduction in output from Q_1 to Q'_1 and a loss of producer surplus shown by the shaded region. If the technical change in region 2 causes supply to shift out far enough, production in region 1 may cease completely. This is shown by the aggregate supply curve $S_1 + S''_2$. Given this supply, P" and Q" are the equilibrium price and quantity. Output in region 1 is reduced to zero at this price -- it is no longer economically feasible for producers in this region to stay in the market.[7]

Many examples of forestry innovations having unequal regional impacts could be cited, such as Southern pine plywood and structural particleboard. During the 1960's, the rapid growth of the Southern plywood industry resulted in a reduced market share for Pacific Northwest plywood producers. In Figure 4, the West Coast producers may be represented by region 1 and Southern producers by region 2. The current growth in the structural particleboard industry primarily in the North Central region is having the effect of shifting the aggregate supply of wood-based panels still further. Some analysts believe that structural particleboard will eventually capture the entire structural panel market (Clark, 1981). In this case, the aggregate supply could be represented by $S_1 + S''_2$, and plywood producers would cease production.

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[7]This abstracts from transportation costs between the two regions in order to simplify the exposition.

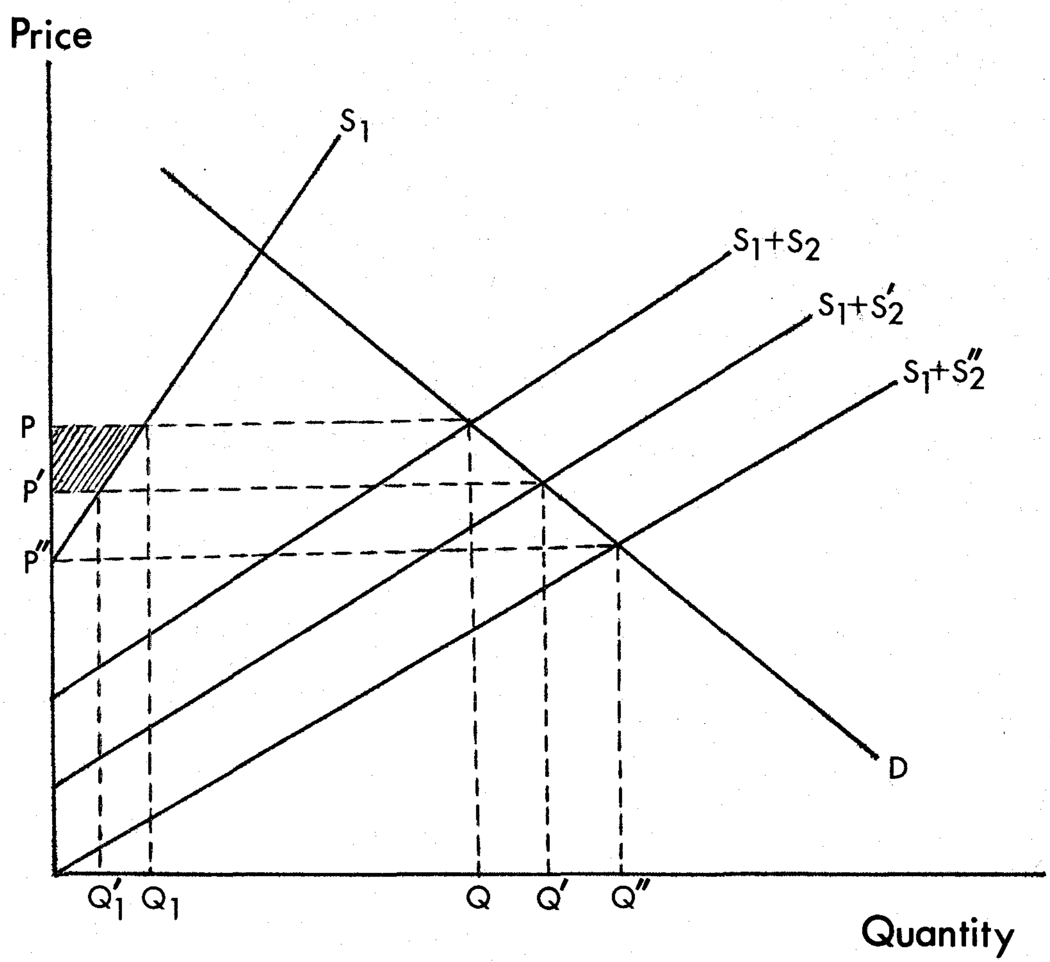

Figure 4. Distribution of research benefits between geographic regions.

5. Concluding Remarks

The distributional effects of research have important implications for public research policy. Technical change resulting from research has a significant impact on the welfare of consumers, producers, and the growth of national economies. A lack of technological innovation in a certain sector of the economy or region also has implications for social and individual welfare. The failure of technical change to become a major source of growth in Argentine agriculture is a case in point (De Janvry, 1978).

The rapid pace of technical change in U.S. agriculture has resulted in difficult adjustment problems for producers and agricultural workers. Research decision-makers in agriculture have been accused of giving insufficient attention to distributional issues. Hightower (1973) documented the frustrations of some with the distributional consequences of the research conducted in the Land Grant University complex:

> Land grant college research is science for sale. Research is undertaken with a very clear understanding of who will profit, but without the slightest concern for those who will be hurt. It is research that effectively is accountable to none but private interests, and ultimately it is corrupt of purpose, (p. 85).

Forestry research administrators, policymakers and evaluators also need to be aware of the welfare impacts of technical change. In light of the importance of these concerns, one of the crucial roles of the economist in evaluating forestry research should be to analyze the income redistribution effects of current and proposed research programs. Knowledge of the distributional impacts of research will better equip decision-makers to make informed choices about the type of research that is funded and the direction of technical change.

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