A Theoretical Framework for Evaluating Social Welfare Effects of New Agricultural Technology

Douglas L. Young

In recent years economists have expressed growing concern over the potential adverse social consequences of technical change in agriculture, both in developed and developing countries [Falcon; Gotsch; Hightower; Schmitz and Seckler]. These critics, while recognizing the great benefits of new technology under appropriate circumstances, have focused attention on two important problems. The first is that the welfare gains and losses produced by efficient technological innovations have sometimes been distributed very inequitably among different groups in society. Second, technologies that are socially inefficient for particular settings have sometimes been introduced. The latter problem is especially serious in developing countries which are confronted by a tempting backlog of technology. Factor price distortions and personal biases often combine to raise the private financial return to investment in capital-intensive technologies above the social return in these labor-abundant economies.

Gotsch and Dorner, among others, have emphasized the need for evaluating distributional as well as efficiency consequences of adopting new agricultural technology. Regional linear programming models, such as those used in studies by Wills and Donovan, are useful for analyzing the microeconomic consequences for employment and income distribution of technology change in a given region. But there is need for a theoretical framework to guide such evaluations of distributional changes. The purpose of this paper is to describe a simple framework for evaluating short-term benefits and costs of adopting new agricultural technologies for specific agricultural operations. The approach is not intended for aggregate analysis of general technological change.

Douglas L. Young is a research assistant, Department of Agricultural and Resource Economics, Oregon State University.

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The Weed Control Example

The theoretical framework presented here was originally developed to evaluate the welfare implications of adopting modern weed control techniques in sugarcane plantations and other areas in Northeast Brazil. Herbicides, in particular, are potentially one of the most labor-saving innovations developed by modern agricultural science, and their premature adoption in Northeast Brazil, in response to government incentives, could substantially increase rural unemployment in one of the most impoverished areas of Latin America.

A regional linear programming model, with farm-size decomposition, is being utilized in work underway to analyze the process of weed control technology adoption and to measure associated benefits and costs. The programming analysis takes into consideration farm-type heterogeneities, seasonal labor supply constraints, environmental variations, and other factors not explicitly treated in this paper. The simplified theoretical framework described here is used to identify, theoretically, the benefits and costs being evaluated. Although the discussion in this paper utilizes the context of the weed control problem, the proposed framework should have applicability to certain similar micro-level problems of technological change.

Classification of Effects of Technical Change

This framework classifies impacts of technological change by origin and by type. Two principal causes for adopting new technology are considered. First, technological breakthroughs or exogenous market forces can make a new technique more efficient at social factor prices. Specifically, they make it possible to expand output with a given resource expenditure, or to produce a given output at a lower cost when all inputs are priced at their social values.[1] These innovations, or forces, are classified as efficiency-enhancing developments in table 1. Secondly, factor price distortions or other forms of government intervention can make adoption of a new technique privately profitable but not socially efficient when evaluated at the true social values of the utilized resources. These forces are identified as market distortions in table 1. Common examples of policies which artifically lower the capital/labor price ratio include direct subsidies or subsidized credit for capital inputs (i.e., farm machinery and agri-chemicals), preferential exemptions from import levies, special exemptions from domestic taxes, payroll taxes and restrictive labor legislation, and legislated minimum wages above equilibrium levels.

The framework also divides welfare effects associated with technical change by type, specifically between efficiency and distributional changes. Efficiency changes are measured with respect to the society's resource cost of producing a given output. Distributional changes refer to the distribution of welfare benefits and costs among different groups in society, and how these changes relate to the society's broad equity goals.

Theoretical Framework

The unit isoquant construct utilized by Timmer for evaluating alternative rice milling technologies in Indonesia provides a useful device for describing the efficiency and distributional implications of a change in techniques brought on by "efficiency-enhancing developments" or by policy-induced "market distortions."[2] The framework is useful

[1] Gittinger discusses the difference between "financial" analyses based on private prices and "economic" analyses based on social prices. The correction of market prices, which may be distorted by several government policies and other influences simultaneously, to obtain "true" social prices can be difficult in practice. But correction is essential to evaluate the economic desirability of a new technology or development project for society as a whole.

[2] The unit isoquant concept was originally developed by Farrell to distinguish and measure the relative technical and economic efficiency of different firms within an industry, a somewhat different problem and application from that addressed by Timmer and by this study.

Table 1. Theoretical classification of welfare changes from technical change

Cause \ Type	Efficiency changes	Distributional changes
Efficiency-enhancing developments	I (Gains)	II (Gains or Losses)
Market distortions	III (Losses)	IV (Gains or Losses)

primarily for evaluating new technologies that are characterized by different factor intensities but which do not increase output significantly through either yield-improving or acreage-expansion effects.

Unit isoquant ABC in figure 1 displays a hypothetical frontier of technically efficient weed control techniques for a given crop, farm type, and ecological setting. Capital requirements per hectare, measured in terms of the social values of utilized materials and capital services, are plotted on the vertical axis, and labor requirements on the horizontal axis. All techniques on the unit isoquant are assumed to give equally effective weed control.[3] By introducing the labor-capital isocost line, PR, in figure 1, Technique B is determined to be the most efficient technology on ABC The lineary segmented isoquants in figures 1 and 2 which generate "corner tangencies" realistically describe the technology selection process within a cost-minimizing linear programming framework. Such discrete choices of technology confront farmers in many real world situations as well.

Consider next the introduction of an "efficiency-enhancing development"—for example, a new, inexpensive, granular herbicide represented by Point E in figure 1. The new herbicide is assumed to produce the same yield response as the old techniques in this setting, so the new frontier of technically efficient methods shifts to AEC and Technique B becomes technologically obsolete. At the same factor price ratio, represented by P'R'

[3] In fact, all the techniques illustrated in figure 1 produced statistically equivalent yields in repeated experimental trials within one Northeast Brazil study area [OSU/EMBRAPA/USAID Project]. Also, in the northeast Brazil case studies, crop acreage levels were largely determined by other factors. In situations where the choice of weed control technique significantly influenced output, this effect should also be considered in the analysis.

parallel to PR, E becomes the least cost and the most socially efficient weed control technique. The development of the granular herbicide generates P-P′ dollars per hectare of efficiency benefits, which represents the reduced resource cost of producing the same output as before. If the new technique is adopted over X hectares, the aggregate short-run benefits would sum to X(P-P′) dollars per year, assuming one crop is harvested per year. In the short run, these gains will be captured in the form of Schumpeterian profits by early adopting farms. Over the long run they will be translated into increased consumer's and/or producer's surpluses.

This procedure for measuring efficiency benefits is fundamentally identical to that utilized by Schmitz and Seckler in their evaluation of the social benefits derived from the introduction of the mechanical harvester in the processing tomato industry, although they did not explain the process within the unit isoquant context. It should be recognized that these measurements may hold valid only for the short run, because over the long run the relative social prices of capital and labor could change greatly. Schmitz and Seckler projected the cost savings of the mechanical tomato harvester through infinity, but this could be a risky practice in a world of rapidly changing factor prices.

What are the distributional losses caused by the switch in weed control techniques? Following Schmitz and Seckler's approach, the direct costs borne by displaced hired labor can be measured by the reduction in the earnings of the relevant labor force after the change. Theoretically, if the gains received by "winners" from the efficiency-enhancing new technology were sufficient to compensate the "losers" for their lost earnings, then all groups could be made at least as well off after as before the inovation. In reality, however, such compensation is rarely paid. Returning to figure 1, total employment in weed control is reduced by the quantity (N_b - N_e) per hectare. Total earnings in weed control are reduced proportionately under the short-run assumption of no change in the price of labor, P_L. The quantity P_L (N_b - N_e) per hectare defines the upper bound on labor's losses. On the other hand, if 100 percent of the displaced workers find equal-paying jobs elsewhere, their short-run losses are zero. Most often, labor's losses will lie somewhere between these two extremes.

The preceding measurements are short-run, and assume certain inflexibilities in wages and labor mobility to rationalize the existence of any unemployment. In a depressed area like the Brazilian Northeast, resulting unemployment could persist

Fig. 1.

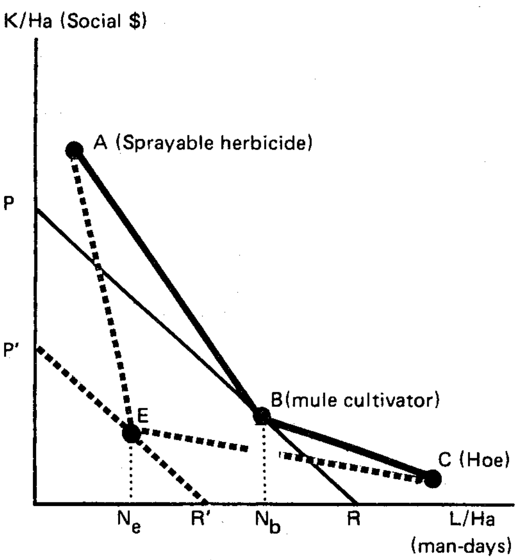
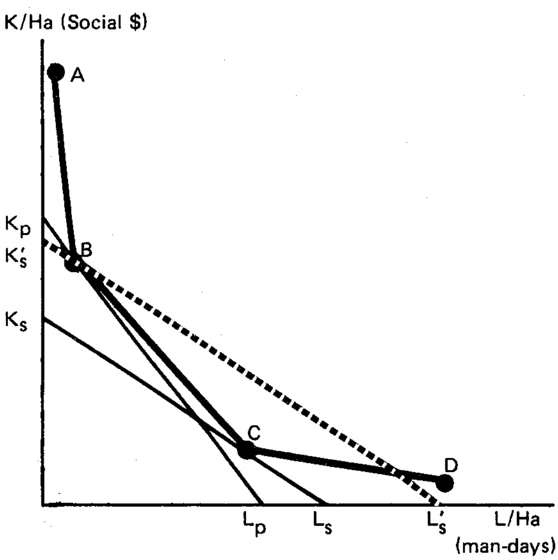


Fig. 2.



for a long time.[4] Also, it could be argued that, over the long run, displaced workers might recoup a portion of their losses through cheaper food prices. But even if technology adoption significantly reduces the market price for the involved commodity, it is unlikely that the displaced workers consume sufficient quantities of the single item to reclaim a significant portion of their lost earnings.

Figure 2 utilizes a similar framework to evaluate the efficiency and distributional implications of a switch in agricultural technology caused by factor price distortions. Isoquant ABCD represents the set of technically efficient weed control systems available. The capital/labor social price ratio is reflected by isocost line K_SL_S, which reveals System C to be the most efficient from society's perspective. Assume, however, that direct and indirect government subsidies for capital inputs, including herbicides and machinery, reduce the private price of capital by 50 percent, while the price of labor remains constant. The capital axis in figure 2 is scaled according to the social value of capital, but the private price of a dollar's worth of capital has been reduced to fifty cents by the subsidy. Consequently, the isocost line KpLp represents the new lower capital/labor price ratio confronting the farmer, and motivates the adoption of B as the least cost technology. Evaluated by the social opportunity cost of the utilized resources (as indicated by $K_S'L_S'$, which permits the purchase of Technology B and is parallel to K_SL_S), the utilization of Technique B wastes (K_S' -K_S) dollars per hectare. These are the "efficiency losses" of Quadrant III in table 1. Adopting farms realize private production cost savings of (L_S - L_p) x P_L per hectare,[5] but their subsidized "modernization" has been costly indeed to society. A switch to Technology B also displaces labor from weed control, and runs the risk of imposing distributional losses on workers in the form of higher unemployment and reduced earnings.

To briefly cite one example of the potential impact of factor price distortions, preliminary results from the coastal sugarcane zone of Pernambuco state in Northeast Brazil indicate that the existing combination of labor payroll taxes and indirect subsidies for herbicides, which reduces the relevant capital/labor price ratio by about 50 percent, could eventurally result in the privately profitable diffusion of herbicides over the entire region, displacing over 90 percent of the labor previously engaged in manual weeding. On the other hand, in the absence of price distortions, it is unlikely herbicides would be profitably adopted on more than one-third of the regional production area.

The point that should be emphasized is that when government price distortions underlie the change in technology, there are no compensating efficiency gains to balance against the welfare losses of displaced workers. Unless there are exceedingly important dynamic or other benefits of a type not considred here, which justify the continuation of these price-distorting policies, their continuation should be seriously questioned.

[4]Employment adjustments may be particularly slow for developing countries because they commonly import herbicides and farm machinery, thereby creating few new jobs through linkages with the domestic industrial sector.

[5]As the price of labor (P_L) has remained constant, it can be used as a numeraire in determining the value of the two isocost lines, K_SL_S and K_pL_p, as perceived by the farmer.

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