Technology Adoption and Agricultural Price Policy

Tracy Miller and George Tolley

Market interventions such as price supports or fertilizer subsidies can lead to gains from speeding up adoption of new technologies, but the policies distort resource allocation. A framework is developed for optimizing policies in light of the adoption-allocation trade off. Based on adoption coefficients and production parameters from third world agriculture, levels and duration of policies are estimated. Sensitivity analyses are performed. Gains are small at best and may be zero or negative in view of farmer costs of adjustment and deadweight losses from taxes.

Key words: deadweight loss, optimizing, private profit, resource allocation, social profit, technology adoption.

If new technologies are desirable, why not use price supports or input subsidies to encourage faster technology adoption? While frequently raised in policy deliberations, this question has received little serious analysis. Particularly neglected has been the conflict or trade off between (a) gains in output as producers switch from old to new technologies and (b) the losses from resource use distortions brought about by price policies.

When output prices are raised, or prices of inputs such as fertilizer are lowered, the profitability of a new technology relative to an old technology may be increased, thus spur­ring adoption. However, the price interven­tions can have resource malallocation effects, in which input combinations both in the new and old technologies are distorted. Moreover, they can stimulate total agricultural produc­tion beyond the point warranted by the re­source costs of the output.

Because of the trade off between adoption benefits and resource malallocation from price distortions, the extent to which output prices can be raised, or input prices lowered, while still achieving gains, is limited. At best, there is some optimum amount that output or input prices should be changed in the pursuit of adoption benefits. Furthermore, only temporary price interventions are justified. As adop­tion proceeds, fewer farmers remain to adopt. Adoption slows down, reducing the gains from adoption. The malallocations meanwhile con­tinue to affect both adopters and nonadopters. At some point, the gains from adoption will no longer justify the price interventions.

How far, if at all, should output prices be raised or input prices lowered to encourage adoption? How long should such policies be in effect? How much is to be gained from such policies? Are there other more desirable poli­cies?

To consider these questions requires an analytical framework in which the trade-offs between adoption benefits and resource malalloca­tion from price interventions can be exam­ined. Toward this end, this article presents a four-part welfare expression based on pro­duction using old and new technologies before and after price interventions. The expression then is used to derive optimizing conditions for the amount of price change to maximize net gains and for the length of time of a price intervention program.

The remainder of the article explores the empirical implications of the optimizing condi­tions. Included are the magnitude of output price and fertilizer price effects on adoption paths and the magnitudes of production coefficients determining resource combination responses.

Policy levels and lengths for price supports and fertilizer subsidies are estimated along with net social gains. Sensitivity of results to the various coefficient estimates are per-
formed, using Cobb-Douglas and CES production functions. Reasons for differences in results between price support and fertilizer subsidies are analyzed. Finally, an overall evaluation is presented in the concluding section.

**Welfare Expression**

Social product, $SP$, is defined as the discounted aggregate net value of production when outputs and inputs are valued at their social opportunity costs. Given a price policy in existence for part of the period during which a new technology is being adopted, social product may be subdivided into product while the policy is in effect and after the policy is terminated. Each of these in turn may be subdivided into product using the old and new technologies:

$$SP = \int_0^T L_t \pi_{sz} e^{-rt} dt + \int_0^T L_t^* \pi_{sz}^* e^{-rt} dt + \int_T^\infty L_t \pi_0 e^{-rt} dt + \int_T^\infty L_t^* \pi_0^* e^{-rt} dt,$$

where subscript $z$ is either $p$ for a price support or $f$ for a fertilizer subsidy; total amount of land, say $L$, is divided at any time between land in the old technology $L_t$ and land in the new technology $L_t^*$; $\pi_{sz}$ and $\pi_{sz}^*$ are the annual net social returns from the old and the new technologies when the policy is in effect; $\pi_0$ and $\pi_0^*$ are the undistorted annual net social returns after the policy is over; and $T$ is the number of years the policy lasts.

A price support or fertilizer subsidy policy increases the amount of land $L_t^*$ in the new technology and reduces the amount $L_t$ in the old technology, raising the second and fourth terms which represent the higher returns from the new technology and at the same time reducing the first and third terms which represent the lower old technology returns (since $\pi_{sz}^* > \pi_{sz}$ and $\pi_0^* > \pi_0$). Costs arise from the distortions in input or product prices that lower the first two terms pertaining to returns during the time the policy is in effect (because $\pi_{sz} < \pi_0$ and $\pi_{sz}^* < \pi_0^*$). An optimal policy sets the policy variables where the marginal gains from increased technology adoption just offset the marginal cost of resource malallocation. The level of the policy price (product price or input price) and the length of time the policy will be in effect are based on a comparison of marginal gains and costs.

**Conditions for Level and Length of Policy**

To determine the optimal level of an output price or input subsidy, set the derivative of the discounted net social product ($SP$) with respect to price equal to zero:

$$0 = \int_0^T L_t (d\pi_{sz}/dP)e^{-rt} dt + \int_0^T L_t^* (d\pi_{sz}^*/dP)e^{-rt} dt + \int_0^T (dL_t^*/dP)(\pi_{sz}^* - \pi_{sz}) e^{-rt} dt,$$

The first two terms are marginal resource malallocation losses from a change in price. These occur during the period of the policy, affecting land utilizing the old technology as well as land in the new technology. The last two terms give the marginal gains from adoption. The third term is the difference in product between the new and the old technology on the land that shifts out of the old technology as a result of the change in price. The fourth term is the gain resulting from the fact that the change in price will leave less land remaining in the old technology after the policy is terminated.

The first two cost terms are often overlooked. For the price set by policy to be optimal, the marginal costs of a change in price
given by the first two terms should just equal the marginal gains from extra adoption due to a change in price given in the last two terms.

To determine the optimal length for the policy, set the derivative of \( SP \) with respect to \( T \) equal to zero:

\[
(3) \quad 0 = L_r(\pi_0 - \pi_{\text{new}})e^{-rT} + L_s^*(\pi^*_0 - \pi^*_\text{new})e^{-rT}.
\]

The first two terms are the resource malallocation costs resulting because an extra year of the policy will entail continuing the price policy distortions for a year on the amounts of land \( L_r \) and \( L_s^* \) that occur in the final year of the policy. The third term to be balanced against these costs is the gain resulting because more land will be devoted to the new technology after the policy if the policy is continued for an extra year.

The duration of the policy should be such that the additional malallocation costs from extending the price distortions one more year just equal the gains from earlier adoption induced by the extension.

**Modeling Adoption**

A myriad of factors have been considered as influences on adoption, as reviewed by Feder, Just and Zilberman, and Thirtle and Ruttan. The typical S-shaped adoption path has been based conceptually on information processes as in Jarvis, Feder and O’Mara, and Stoneman and David. Further conceptual work is needed to explicitly model the neglected role of prices in the information processes.

Meanwhile, not concentrating on prices as such, a body of empirical work has considered the hypothesis that the rate of adoption depends on the difference in profitability between the new and old technology. The hypothesis has been supported by Griliches, Mansfield, Globerman, Romeo, Sukhatme, Dixon, Jarvis, and Jamison and Lau.

**Theory of Adoption**

The present study models the effect of price policies on adoption through their effects on profitability. An adoption path with and without a price policy is needed. This leads to a formulation where an adoption path is followed whose flatness is influenced by the profitability of the innovation. A price policy that increases the profitability of a new technology makes the path less flat, thus speeding up adoption.

A combination of two exponential curves will be used to model adoption:

\[
(4) \quad L_t^+ = (e^{b_0 t} - 1)L \quad \text{if} \quad L_t^* < \bar{L}/2
\]
\[
= \bar{L} - \bar{L}/2e^{-3b_0 t} - \bar{L} \quad \text{if} \quad L_t^* > \bar{L}/2 \quad \text{or} \quad t > t,
\]

where \( \bar{L} \) is the amount of land beginning in the old technology on which the new technology will eventually be adopted, and \( L_t^* \) is the amount of land on which the technology has been adopted by time \( t \). By time \( t \), half the land (\( \bar{L}/2 \)) is in the new technology, with \( \bar{L}/2 \) being at the inflection point where the rate of adoption stops increasing and starts decreasing.

This form replicates the S-shape of adoption, and it is less computationally cumbersome than the logistic and cumulative normal forms. Like those forms, it ignores modest deviations from symmetry between the speeding up in early stages and the slowing down in later stages caused by heterogeneity among producers in traits such as farm size and education.

The adoption coefficient, \( b_0 \), determines the degree of flatness of the adoption path; it is modeled here as proportional to the difference in profitability between the new and old technologies:

\[
(5) \quad b_0 = b_1(\pi^*_0 - \pi_0),
\]

where \( \pi^*_0 \) and \( \pi_0 \) refer to profitability under the new and old technologies, respectively.

**Appropriate Level for Adoption Coefficient**

Using a model of the form \( Y_t/Y_{t-1} = (Y_t^*/Y_{t-1})^b \) to represent adjustments to relative price changes, Griliches found annual adjustment coefficients ranging from .15 to .31 in U.S. agriculture. Sukhatme found average adoption coefficients of \( b = .08 \) for rice and \( b = .06 \) for wheat. He used a linear model where the percent who have adopted at year \( T \), \( P_T = a + bT \).
Barker, Herdt, and Rose present data showing that, in parts of Asia where new rice varieties were widely adopted, the percentage of farmers who had adopted rose from less than 10% to over 90% in six years. As another example, Herdt shows that two-thirds of farmers switched to modern rice varieties in one district of the Philippines, while nearly all farmers in another district adopted the new varieties over a four-year period.

In the present study, a baseline value of $b_0 = 0.05$ is used for the adoption coefficient in the absence of a price policy; this value implies an adoption rate of about 7.5% per year at the midpoint of the adoption process. It is comparable to the results from Sukhatme and, being conservatively low, will accentuate the potential gain from policy.

Modeling Production

Let the production functions for output per hectare be $Q = g(F, N)$ under the old technology and $Q^* = g^*(F^*, N^*)$ under the new technology, where $F$ is the quantity of fertilizer or other purchased inputs intensively used in the new technology and $N$ is the quantity of the remaining nonland inputs including labor.

Private and Social Returns in Terms of Producer Variables

In terms of per hectare quantities, the private profitabilities $\pi$ and $\pi^*$ determining the adoption coefficient in (4) are

$$\pi_i = P_iQ_i - P_{F_i}F_i - W_iN_i,$$

and

$$\pi^*_i = P_iQ^*_i - P_{F_i}F^*_i - W_iN^*_i,$$

where $P$ is price of output, $P_F$ is price of the inputs intensively used in the new technology, $W$ is the price of other nonland inputs, and the $Q$'s, $P$'s, and $F$'s are the quantities chosen by farmers in response to the prices.

Three sets of prices are of interest. First, when an output price support policy is in effect, the price of output $P$ will be raised above free market levels with the other prices remaining the same ($i = p$). This set of prices determines adoption during a price support policy. Second, under an input subsidy, the input price $P_F$ will be below free market levels and will determine adoption during the time when the policy is in effect ($i = f$). Third, without any policy intervention, the prices are all at free market levels ($i = 0$) determining adoption after the policy is ended.

In addition to the private profitabilities, the social profitabilities $\pi_{sz}$ and $\pi^*_{sz}$ are needed that appear in equations (1), (2), and (3) defining social product and giving the conditions for optimum level and duration of policies. Social profitabilities are calculated using the quantities determined by private decisions but valuing them at social prices, here assumed to be free market prices. The result is

$$\pi_{sz} = P_0Q_z - P_{F_0}F_z - W_0N_z,$$

and

$$\pi^*_{sz} = P_0Q^*_z - P_{F_0}F^*_z - W_0N^*_z,$$

where the subscript $O$ indicates a social price and the $Q$'s, $F$'s, and $N$'s for $z = p$ or $f$ correspond to whether a product price or input subsidy policy is being considered.

While the prices used in calculating the social profitabilities are different from privately perceived prices when a pricing policy is in effect, the quantities indicated by the subscripts are the same as those in the definitions of private profitability. The free market profitabilities $\pi_0$ and $\pi^*_0$ appearing in (1), (2), and (3) for the time when the policy is over have the same prices with or without a policy and so are already given by private profitability for the case with no policy intervention.

The approach is to use specific production function forms to find farmer input and output choices as influenced by privately perceived prices under the new and old technologies. These results then are used to calculate the private profitabilities determining adoption and the social profitabilities needed to evaluate social product.

Social prices for output and nonland factors are taken as given. They correspond to free market prices that would prevail with international determination of product prices, constant cost input industries, and mobility of labor. Other price assumptions could be treated in refinements. This includes the manipulation of urban selling prices, along with complications due to quality differences between new and old varieties, seasonality, related crops, multiple cropping, and alternative factor supply assumptions for the short and long run, dealt with in a broader context in Tolley, Thomas, and Wong.
**Functional Forms**

Assume a CES production function

\[ Q = a\left(aF^{-\rho} + \beta N^{-\rho} + \gamma L^{-\rho}\right)^{-1/\rho}, \]

where the elasticity of substitution \( \sigma = 1/(1 + \rho) \). The Cobb-Douglas is the special case where \( \sigma = 1 \). Profit-maximizing incentives lead to a tendency for the marginal value product to equal price for each factor, implying that factor shares will tend to equal elasticity of output, or

\[ s_F = (aP_F/P)^{\alpha \sigma}, \quad s_N = (aW/P)^{\rho \sigma \beta}, \]

where \( s_F \) and \( s_N \) are the factor shares for the inputs \( F \) and \( N \). The shares simplify in the Cobb-Douglas case to \( \alpha \) and \( \beta \).

The shares in (6) maximize social product when the social prices \( P_F, P_W, \) and \( P_0 \) are inserted in the right sides, with use of other prices giving lower than maximum social product. Raising output price above its social price results in using more nonland inputs per hectare and more product output than will maximize social product. Lowering fertilizer price has similar effects and gives particularly pronounced incentives to increase fertilizer relative to the optimum amount.

To solve for output per hectare, set land equal to one and substitute the factor shares times the value of output divided by the factor price into the production function. Substituting the expressions in (6) and simplifying gives

\[ Q_p = a((1/\gamma)(1 - X_1^\gamma - X_2^\gamma))^{1/\rho}, \]

where

\[ X_1 = \alpha(P_F/aP)^{\rho}, \quad X_2 = \beta(W/aP)^{\rho}. \]

In the Cobb-Douglas case, letting prices equal one in the absence of policy, the solution is

\[ Q_p = Q_0 P_0^\delta (1/P_F)^{\delta \alpha}(1/W)^{\delta \beta}, \]

where

\[ \delta = (\alpha + \beta)/(1 - \alpha - \beta), \]
\[ \delta_\alpha = \alpha/(1 - \alpha - \beta), \text{ and} \]
\[ \delta_\beta = \beta/(1 - \alpha - \beta). \]

Given the solution for output, the factor share conditions can be used to solve for the quantities of the factors. The above expressions without asterisks pertain to the old technology. Identical expressions are obtained with asterisks pertaining to the new technology, completing the information needed to calculate the various \( \pi \)'s determining adoption and social product.

**Magnitude of Production Coefficients**

In estimating a model of technology adoption similar to ours, Sukhatme found fertilizer share averaging about 5% for traditional wheat and 10% to 11% for new varieties of rice or wheat. Barker, Herdt, and Rose present data from a number of countries in Asia showing that fertilizer shares average 5% or less for traditional varieties and generally exceed 10% for modern varieties of rice. Other studies provide empirical support for average fertilizer shares ranging from 5% to 20% in various countries (Hayami and Ruttan; Kawagoe, Keijiro, and Hayami). In the initial case to be considered here, we assume a fertilizer share of 5% under the old technology and 10% under the new.

Sukhatme finds labor shares of 10% to 25% in India. For other purchased inputs he finds a share between 30% and 40%. Hayami and Ruttan; and Kawagoe. Keijiro, and Hayami find average labor shares between 40% and 50%. Both of these studies give estimates of the share of land and machinery ranging from under 30% to over 50%. Data from Barker, Herdt, and Rose generally indicate that the share of labor and other purchased inputs is 50% or less on modern or transitional rice farms and somewhat higher where traditional methods are used. In this study a labor share of 60% is assumed under the old technology and 50% under the new.

Sukhatme shows that the increase in profits resulting from the adoption of high-yielding varieties of rice and wheat in the Punjab was between 20% and 30% of variable costs, allowing for differences in quality and product price. He also found that using the high-yielding varieties resulted in increases in yield of 62% for wheat and 52% for rice. Barker, Herdt, and Rose summarize studies indicating that modern varieties of rice yielded between 10% and 100% more than traditional varieties. Herdt presents data showing that rice yields increased between 76% and 108% in the Philippines between 1966 and 1981 as the result of the adoption of new technology. In our initial case we optimistically consider a technological change that doubles output per hectare as the base case.
Welfare Estimates

Given the ranges of parameter values suggested by the studies cited above, a solution can be obtained for the optimal length and level of policy.

Method of Solution

In the absence of tractable closed-form solutions of equations (2) and (3) giving level and length of policies, a computer program was developed to find the maximum social product by iteration. Starting with an assumed level and length of policy, the empirical coefficients from the production model were used to calculate per hectare outputs and inputs under the old and new technologies, applying prices with and without policy. The results were used to calculate profitabilities of adoption with and without policy and to find the adoption coefficient during the policy by changing the no-policy adoption coefficient \( b_0 \) of 0.05 in proportion to the difference in private profitability of adoption, as implied by equation (5). The exponential adoption path (4) determined by profitability during the policy was used for the policy period. At the termination of the policy, the lower adoption coefficient for the no-policy case was used, starting the exponential from its level at the end of the policy. Using the per hectare quantities from the production model, the social profitability implied by the adoption path was calculated from (1). The objective function was well behaved, and the process was repeated to find the output price policy and the input subsidy giving maximum social product.

Output Price Policy

Table 1 gives the results for a policy of raising output price.

*Base case.* In the base case, for which coefficient values were given in discussing the production model, the policy that will maximize social value lasts for eight years with a price support 18% above the free market price.

This policy increases net social product from the crop by 3.5%, giving an increase in social product somewhat less than 1.5% of the gross value of production. Government costs consists of losses from making purchases at the policy price and reselling at the lower free market price. They are 9.2% of gross farm income and are six times greater than the social gains from the policy.

*Sensitivity.* Figure 1 shows the effects in the base case of levels and duration of price support different from the maximizing values given in table 1. The level and duration of the price can be varied by up to one-third without reducing social product by more than 0.5% from the maximum.

However, the net social product becomes negative after a maximum level of output price is reached. As the program lengthens, the break-even level falls from over 40% for a policy lasting less than five years to under 25% for one lasting more than twenty years.

Now we proceed beyond the first column in table 1 to cases showing effects of alternative coefficient values on the optimal policy. Reducing the elasticity of substitution, \( \sigma \), results in a substantial increase in the length of a price support policy, with a corresponding reduction in social product. The increase in social product is more than twice as great, but the policy also is more than twice as costly for the government. The higher levels occur because of less distortion in output in response to the higher price when \( \sigma \) is smaller.

Increasing the adoption coefficient reduces the returns from policy. The faster the rate of
adoption in the absence of policy, the less a policy can increase returns. Because the assumed rate of adoption is slower than reported rates from a number of countries, the potential gains from policy might often be lower than the base case suggests.

Varying the fertilizer share under the old technology makes little difference in optimal policy level, length, or social profitability. Increasing the labor share by twenty percentage points for both the old and the new technology reduces land's share by almost 50%. With a small land share, the optimal level of policy is considerably smaller and so is social product.

If the ratio of output between the new and old technologies is 1.25 instead of 2, the optimal level of a price support will be less than 100\% above the free market price, and net social product will increase by less than 0.5\% compared to the situation with no policy.

The base case, assuming all output is marketed, is strictly applicable when factors are paid in cash rather than in kind and none of the return to land is held back for producer consumption. The alternative case shown in the next to last column of table 1 comes closer to reality in assuming that the fraction of output marketed is 70\%, although the fraction is still high. Suppose a policy existed in which the government would purchase all output farmers chose to sell at a price above the free market level and at the same time the government was willing to sell to all comers at the free market price as determined, say, on international markets. Then producers would have incentives to sell 100\% of their output to the government, pay hired factors in cash, and purchase back any of the commodity needed for their own consumption on the open market. They would profit by the price support offered on every single unit of production. The fact that price support policies do not immediately result in 100\% marketed surpluses suggests that under actual policies, government does not hold down selling prices in rural areas. Rather, government allows consumer prices to rise in rural areas along with the purchase price the government pays to farmers, diminishing the incentives to profit by arbitrage on the price support policy. The 70\% marketed surplus case in table 1 corresponds to such a case, where labor is paid in kind and producers are neither benefitted nor harmed by policy on the proportion of output that they consume.

Because expenses are the same regardless of marketed surplus, profitability per hectare is equal to profitability given earlier, \( \pi_p \) with 100\% marketed surplus, minus (a) gross receipts used in deriving \( \pi_p \), plus (b) gross receipts with less than 100\% marketed surplus. The quantity (a) is total output multiplied by
the support price or $PQ$, and (b) is the value of marketed output at the policy price plus the value of the nonmarketed output at the no-policy price of 1 or $PQ_s + (Q - Q_s)$, where the symbols apply to the old technology and analogous expressions with asterisks are obtained for the new technology. Because the incentive to adopt is profitability with the new technology less profitability with the old technology, subtracting one result from the other gives $\pi_p^* - \pi_p - (P - 1)(1 - \lambda)(Q^* - Q)$ as the incentive to adopt where $\lambda$ is the fraction of output that is marketed. This result indicates the adjustment to be made to the earlier incentive to adopt $\pi_p^* - \pi_p$ when the fraction marketed is less than one.

As shown in table 1, reducing marketed surplus to 70% reduces the increase in social product from 3.5% in the base case to less than 0.5%. It also reduces the optimal price support level to less than 10%.

Finally, the results discussed so far pertain to a situation where the policy starts in year 0 before any adoption has taken place. More realistically, a policy can be expected to start only after field experience has verified that widespread adoption will be warranted. As shown in the last column of table 1, if the policy does not begin until adoption has taken place on 25% of the land, social product is reduced by more than 50%. A policy implemented after 50% adoption will not improve welfare perceptibly (less than 0.1% increase in social product).

**Fertilizer Subsidy**

Results for subsidizing an input intensive in the new technology are shown in table 2. **Base case.** Using the same base case assumptions as above for the price policy, a fertilizer subsidy attempting to maximize social gains will reduce fertilizer price 40% below its free market price and will last seven years. The discounted social product from production will be 1.6% greater than in the absence of policy and will amount to 0.6% of gross farm income. The taxpayer cost is the amount of fertilizer used times the difference between the free market and subsidized price of fertilizer; it is 1.7% of gross farm income or about three times as great as the social benefit of the policy.

**Sensitivity.** That a fairly wide range of nearly maximizing values exists can be seen in figure 2, where isoprofit curves are plotted for combinations of input subsidy level and length, using the parameter values of the base case. The duration of the policy can be varied by up to one-third without reducing profitabil-

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**Table 2. Results for “Optimal” Fertilizer Subsidy—Sensitivity Analysis**

<table>
<thead>
<tr>
<th>Alternative Parameter Values</th>
<th>Subsidy as a Percentage of Free Market Price of Fertilizer:</th>
<th>Duration of Program (years):</th>
<th>Percent Increase in Social Product from Crop:</th>
<th>Increase in Social Product as Percent of Gross Farm Income:</th>
<th>Government Costs as Percent of Gross Farm Income:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity of Substitution</td>
<td>$\sigma = 0.5$</td>
<td>Adjustment Coefficient</td>
<td>$b_0 = .1$</td>
<td>$s_F = .1$, $s_F = .05$, $s_F = .2$</td>
<td>$s_N = .8$, $s_N = .7$</td>
</tr>
<tr>
<td>Base Case</td>
<td>40</td>
<td>55</td>
<td>45</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>3</td>
<td>10</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>1.6</td>
<td>0.9</td>
<td>0.5</td>
<td>0.2</td>
<td>1.2</td>
<td>0.5</td>
</tr>
<tr>
<td>1.7</td>
<td>4.9</td>
<td>1.1</td>
<td>1.2</td>
<td>2.1</td>
<td>1.4</td>
</tr>
</tbody>
</table>

* See table 1 for the assumptions that apply to the base case. As in table 1, the optimal policy is calculated with the same parameters as the base case except for the changes shown.
When the share of output going to land is smaller (because of a larger labor share), returns without policy are lower, and the percentage increase in social product resulting from policy will be correspondingly larger; however, the increase as a percentage of gross sales is about the same as in the base case.

Finally, if the fertilizer subsidy is implemented after the new technology has been adopted on 25% of the land, the net social product is only about one-third as large as when the subsidy is implemented before any adoption. A subsidy implemented after 50% or more adoption will have a return less than one-sixth as large as that of a policy implemented when the technology is first available.

Comparison of Price Support and Fertilizer Subsidy

Duration of either a price support or a fertilizer subsidy policy is rather similar, ranging from three to ten years depending on the case considered. The percentage change in fertilizer price is generally larger than the percentage change in output price.

The fraction of output marketed affects the output price policy but not the fertilizer subsidy. When 100% of output is marketed, the social gains and the government costs are substantially higher under an output price than a fertilizer price policy. In the more realistic case where 70% is marketed, the increase in profitability of adoption from an output price increase is reduced, and at the same time the subsidy is not paid on all output. This lowers both social gains and government costs so that the social gains of a price policy are below the corresponding figures for a fertilizer subsidy.

Concluding Comments

The results suggest that output price and fertilizer subsidies can affect the rate of adoption but still have only a minor effect on social welfare. The movement away from an old technology may represent a gain, but it is partially offset by inefficiency in resource use.

The results in this article likely overstate the true benefit of price policy. If farmer costs of adopting new technologies were included, the policies would encourage some farmers, for whom the social returns were not large enough.
to cover the cost of adoption, to adopt the new technology, thus lowering overall social gains.

Social profitability is further reduced if administrative costs and the deadweight welfare losses from the taxes necessary to make the government transfers to farmers are introduced. Musgrave and Musgrave suggest that a likely middle figure for estimates of the deadweight loss of the average tax dollar on labor income is 15%. Deadweight losses on the marginal tax dollar are likely to be considerably higher than this. Deadweight costs of 15% of government costs or greater will reduce social returns to zero for a price support program begun when the technology is introduced, if all output is marketed. With a fertilizer subsidy, deadweight losses would have to be at least 35% on the marginal tax dollar to reduce social returns to zero, which could easily happen under a highly progressive income tax system (Browning).

The requirement that a policy be terminated within a few years is a formidable obstacle to implementation in view of public choice considerations in third world agricultural price policies analyzed among others by Miller and Krueger, Schiff, and Valdes. A more refined economic approach, using control theory, could consider an optimal output price or fertilizer subsidy that varies through time instead of being fixed for a finite time as in this article. The likely outcome would be a larger initial price distortion which would then begin to diminish in an attenuated fashion, reaching zero at a later time than in the present analysis. Even more than for termination of a fixed level subsidy, the ability of actual policy to fine tune in this manner is open to question.

This article has focused on the trade off between adoption and resource malallocation without introducing other goals of price policies, as dealt with in Tolley, Thomas, and Wong, which would further complicate attempting to use price policy to foster adoption. The analysis has not dealt with tax, credit, education, and extension policies affecting adoption that would merit consideration before price policies. Welch and Huffman are among those who discuss the role of education in improving the allocative efficiency of farmers.

Do price incentives have any role at all as a tool to encourage use of modern technologies? In contrast to the public programs considered here, private sellers of inputs used in a new technology might find it in their interest to offer one time promotional price discounts to new customers that would be self-liquidating as use of the technology spread.

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