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EQUITY AND EFFICIENCY IN AGRICULTURAL PRODUCTION SYSTEMS

by

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1. Introduction

A major issue throughout the development world relates to the possibility of improving the well-being of the poorest groups of society without massive, abrupt, structural changes. Given the scarcity of resources, a more nearly equal distribution may be necessary to move or maintain the poorest strata of the population above a certain poverty line. Moreover, policymakers and the general population may find a certain distribution of income or welfare more favorable than some other distribution.

Over the last decade, the focus of attention in the development community has shifted from preoccupation with economic growth to some emphasis on distribution. Some recent research has cast doubt on the generality of neoclassical assumptions regarding the negative effects of redistribution on the incentives to work and save (Krishna). Some countries, particularly Yugoslavia, China, Korea, and Taiwan, have successfully reconciled growth with poverty reduction even in the early stages of development. Moreover, the Taiwanese case has demonstrated that, with a suitable growth pattern, growth and equity is most easily reconciled in the agricultural sector.

The equity and efficiency impacts of selected government policies have been addressed by a number of different frameworks, most of which are based on aggregative relationships. Generally, aggregative relationships are specified for an agricultural sector and a nonagricultural sector. The microeconomic foundations of these frameworks, however, are not generally specified. As a result, the thorny problems of aggregation are pushed aside.

The purpose of this paper is to advance a framework for evaluating the impact of governmental policies on agricultural production systems that is internally consistent at both the microlevel and at the aggregate level. Various measures will be used to assess the distributional or equity consequences of governmental policies. In the case of growth or efficiency, the framework focus is on the incentives and constraints for technological adoption. Both the efficiency and distributional consequences of various policies are shown to depend upon landownership, land utilization, and the technology associated with land assets.

Without loss of generality, a stylized model involving two technologies, traditional and modern, is specified. At both the micro- and the aggregate level, the framework admits a number of important features including uncertainty, varying degrees of risk aversion, both fixed and variable costs of technological adoption, and credit as well as land constraints. The model design allows the evaluation of a wide array of various policies. This set of policies includes particular instruments often pursued by developing country governments. In particular, we examine price support, credit-funding enhancement, credit subsidies, fixed crop insurance, price stabilization, input subsidies, and extension promotion.

In the determination of the growth and distributional consequences of governmental intervention, a comparative evaluation of the above policies is performed. However, it should be noted that the model design is readily amendable to investigating the efficiency and equity consequences of integrated, comprehensive sets of policy. The latter evaluations can be most usefully achieved once the model is empirically implemented. It is expected that, in an empirical context, even though the distribution of income or landholdings might be quite stable under a single policy regime, egalitarian development strategies can be determined which involve an integration of various policies. In a normative context, multiple-objective programming models can be easily formulated from the framework. The implications of various trade-offs between equity and efficiency can thus be determined.

The basic microeconomic foundations of the framework are developed in section 2. Section 3 focuses on the microeconomic behavior of various farmers under alternative policies. Aggregation operators are applied in section 4 to capture the relevant macrolevel causal relationships. Finally, the concluding section 5 examines the operational use of the developed framework. Formal derivations of the important relationships are presented in Appendices A and B.

2. The Model

Consider initially a single farm with fixed landholdings, L, valued at price, p_L, and a traditional technology involving a subjective distribution of net returns per hectare $\pi_0 = p_0 y_0$ with mean $E(\pi_0) = m_0$ and variance $V(\pi_0) = \sigma_0$ where p_0 and y_0 are the price and yields, respectively, under the traditional technology. Suppose a new technology is introduced under which the farmer can allocate some of his land to the traditional crop (at traditional costs) and some of his land to a new crop (or a new method of producing the same crop).

The second crop (technique), which will be referred to as the "modern crop," may be a high-yielding variety or a cash crop utilizing a modern input such as fertilizers, insecticides, and improved seeds. On the other hand, it may be more vulnerable to weather variations so that there is a relatively greater degree of uncertainty regarding the returns per hectare. Additional (and subjective) uncertainty may also accompany the modern crop due to the fact that the farmer is less familiar with the new technology. Considering this factor, the modern crop may be viewed as more risky even if, in reality, it is not more susceptible to extreme weather situations than the traditional crop.

Suppose production of the modern crop requires a cost of w for the modern input per hectare to attain a subjective distribution of net returns per hectare π_1 with mean $E(\pi_1) = m_1$ and variance $V(\pi_1) = \sigma_1$. Suppose the (opportunity) cost of funds used to finance the modern input is given by r so that $\pi_1 = p_1 y_1 - w(1 + r)$ where p_1 and y_1 are the price and yield of the modern crop, respectively, and $p_1 y_1$ is normally distributed. Also, suppose that net returns of the traditional and modern crops are correlated with $\mathrm{corr}(\pi_0, \pi_1) = \rho$.

Specifically, assume

$$\begin{pmatrix} \pi_0 \\ \pi_1 \end{pmatrix} \sim N\left[\begin{pmatrix} m_0 \\ m_1 \end{pmatrix}, \begin{pmatrix} \sigma_0^2 & \rho\sigma_0\sigma_1 \\ \rho\sigma_0\sigma_1 & \sigma_1^2 \end{pmatrix}\right]$$

with the relevant covariance matrix assumed to be positive definite; further reasonable assumptions include $m_0 > 0$, $m_1 > 0$. Also note that the variances and covariances include subjective uncertainty about yields and market access (prices) and may thus be influenced by both experience and extension efforts.

The farmer must either allocate all his land to the traditional technology or incur a fixed set-up cost, k, for the new technology in which case he can allocate his land in any proportion between the two technologies. Thus, the investment decision is a discrete choice whereas the land-allocation decision is a continuous choice. In addition to the fixed set-up cost, k, for which the annualized cost is rk, the farmer also incurs a variable cost, w per hectare, for adoption. Both of these costs must be considered in the context of available credit, K, in making the adoption decision. The credit constraint is

$$I(k + wL_1) \leq K$$

where I = 0 if the modern technology is not adopted, I = 1 if the modern technology is adopted, and L_1 is the amount of land allocated to the new technology.

Now assume that the farmer is risk averse with utility function U(•) defined on wealth, U' >, U'' $\leq$ 0. Suppose that wealth, W, at the end of each season is represented by the sum of land value, p_L L, and the net return from production. Where L_0 is the amount of land allocated to the traditional technology, the decision problem is thus

$$\max_{\substack{I = 0,\, 1 \\ L_0, L_1}} EU[p_L\, L + \pi_0\, L_0 + I\, (\pi_1\, L_1 - rk)] \tag{1}$$

subject to

$$L_0 + IL_1 \leq L$$

$$I(k + wL_1) \leq K$$

$$L_0,\ L_1 \geq 0.$$

The results below assume that risk aversion is not so great or returns so poor as to prevent use of all available land. Thus, the land constraint can be replaced by a strict equality.

To solve this decision problem, first consider the choice of land allocation given the adoption decision. Assuming full utilization, the optimal decision with $I = 0$ is $L_0 = L$. Thus, expected utility is

$$U_0\ (L) = EU[(p_L + \pi_0)\ L]. \tag{2}$$

Alternatively, given adoption, the objective of the decision problem in (1) becomes

$$\max_{L_0, L_1} EU[p_L\ L + \pi_0\ L_0 + \pi_1\ L_1 - rk] \tag{3}$$

subject to

$$L_0 + L_1 \leq L$$

$$k + wL_1 \leq K$$

$$L_0,\ L_1 \geq 0.$$

The solution to this problem is approximated by (see the Appendix A):

$$L_1 = \bar{L}_1 \equiv \begin{cases} 0 & \text{if } L_1^* < 0 \text{ or } k > K \\ L_1^* & \text{if } 0 \leq L_1^* \leq L \text{ and } (K - k)/w > 0 \\ (K - k)/w & \text{if } L > L_1^* > (K - k)/w > 0 \\ L & \text{if } (K - k)/w > L \text{ and } L_1^* > L \end{cases} \tag{4}$$

and $L_0 = \bar{L}_0 \equiv L - \bar{L}_1$

where

$$L_1^* = \frac{E(\Delta\pi)}{\phi V(\Delta\pi)} + L\ R \tag{5}$$

$$R = \frac{\sigma_0^2 - \rho\sigma_0\sigma_1}{\sigma_0^2 + \sigma_1^2 - 2\rho\sigma_0\sigma_1} \tag{6}$$

$$\Delta\pi = \pi_1 - \pi_0 \tag{7}$$

$$\phi = \frac{-U''(\overline{W})}{U'(\overline{W})} \tag{8}$$

$$W = p_L\ L + m_0 L + E(\Delta\pi)\ L_1 - rk. \tag{9}$$

Note that ϕ is the coefficient of absolute risk aversion at expected wealth.

This result is intuitively clear from Figure 1 upon noting that (3) is a concave programming problem with linear constraints. Assuming full utilization of land, the optimal solution must lie on the line ac. For mathematical convenience, Appendix A derives L_1^* as the optimal solution for L_1 when negative choices for land quantities are possible (corresponding to the broken lines in Figure 1). Thus, by concavity of the objective function, the optimum is at point c if $L_1^* < 0$. If the credit is abundant (e.g., $K = K_1$ in Figure 1), then the optimum is at point a if $L_1^* > L$. However, if credit is insufficient to allow complete adoption such as if $K = K_0$ in Figure 1, then the segment ab is infeasible because of credit limitations. Thus the optimum is at point b if $L_1^* > (K - k)/w$.

To determine the technology choice, let

$$U_1\ (L, \bar{L}_1) = EU[p_L\ L + \pi_0\ (L - \bar{L}_1) + \pi_1\ \bar{L}_1 - rk].$$

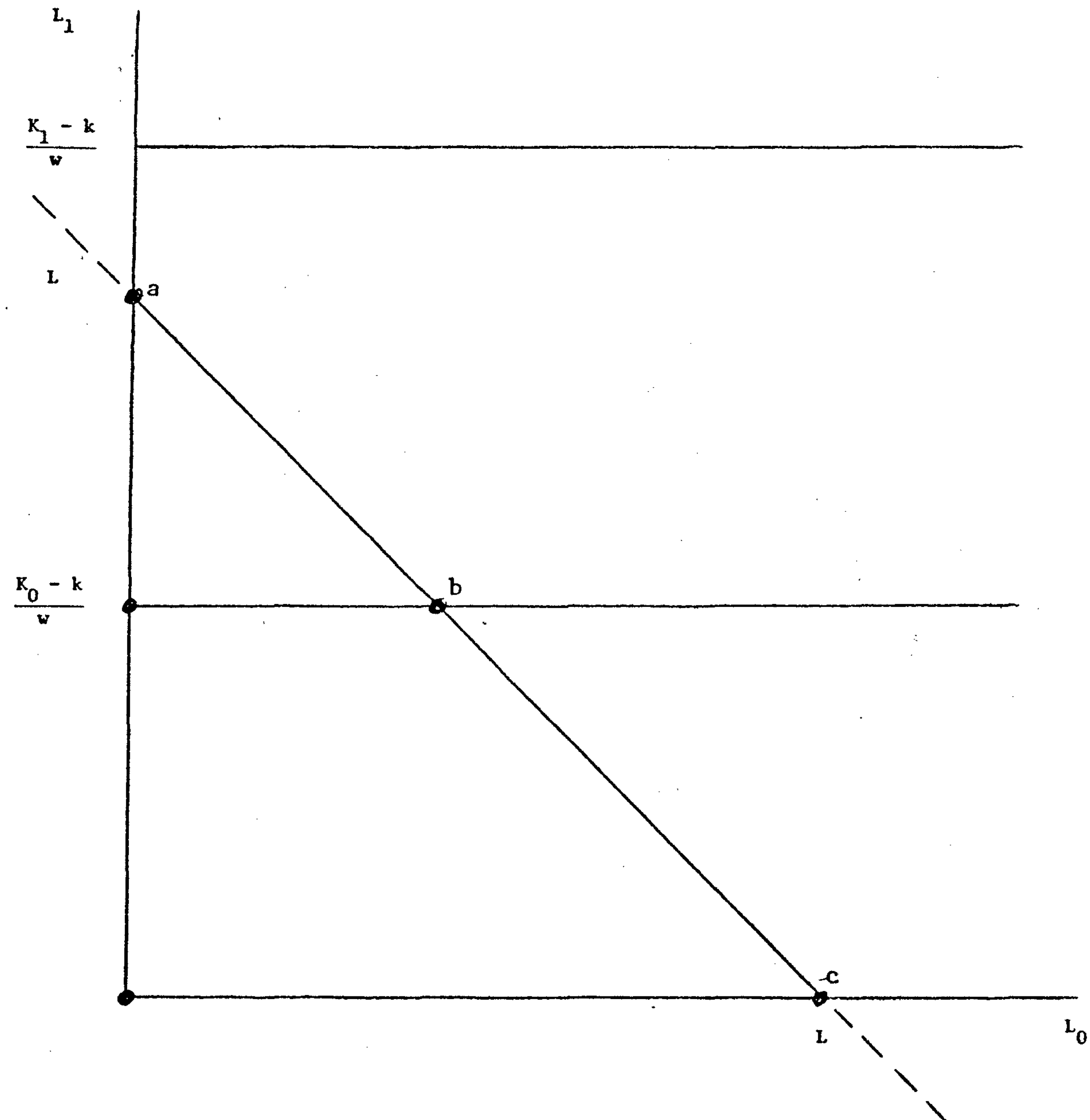

Figure 1

Assuming either that the farmer is myopic (or considers future periods to be like the current one), the farmer selects the traditional technology if $U_0 > U_1$ and selects the new technology if $U_1 > U_0$.

3. Behavior of Individual Farmers Under Alternative Policies

Based on the model of individual farmers in section 2, Appendix A investigates the mathematical properties of farmer behavior under several alternative development policies. This is done by first examining the effects of alternative policies on farmers given the adoption decision and then investigating effects on adoption decisions. The results are summarized in the propositions of this section. The policies considered are price support, credit-funding enhancement, credit subsidy, fixed crop insurance, price stabilization, modern input subsidy, cost subsidy extension, promotion, and land reform. Price support, crop insurance, and price stabilization are considered both in cases where the new technology is associated with a new and different crop and where the new technology is simply a new production method or variety of the same crop (in which case the controls may also directly affect farmers who are using the old technology).

The parameters through which these policies are reflected in the model are m_1, σ_1, w, K, k, r, L, m_0, and σ_0. Specifically, a price support is assumed to cause the expected returns per hectare under the new technology, m_1, to increase, and the variability of returns per hectare under the new technology, σ_1, to decrease. If the price support also applies to the existing crop, then similar effects are assumed for the old technology except that the effect on both expected returns and variability of returns per hectare under the old technology is relatively less ($dm_0 = \beta_m \, dm_1$ where $0 < \beta_m < 1$ and $d\sigma_0 = \beta_\sigma \, d\sigma_1$ where $0 < \beta_\sigma < 1$).[1]

Credit funding enhancement (for example, through an additional public source of funds) is assumed to increase the farmer's credit limit, K, at the same cost of capital as otherwise. Credit subsidy, either directly or through loan guarantees, is assumed to lower the effective cost of capital, r.

Crop insurance is assumed to be actuarially fair and lower the variability of returns per hectare under the new technology, σ_1, without affecting expected returns per hectare. If the new technology applies to the same crop as the old technology (crop insurance applies in both cases), then similar assumptions apply to the old technology except that the effect on the variability of returns per hectare under the old technology is relatively less (as suggested by the assumption that the new technology is viewed as relatively more risky). The effect of price stabilization is thus the same as for crop insurance.

A subsidy on modern input use is reflected by a reduction in variable input costs per hectare, w. A subsidy on the fixed cost incurred in adoption is reflected by a reduction in k.

Several types of extension effects are considered. Extension contacts can cause a farmer to increase his subjective expectations of returns per hectare under the new technology, m_1, and/or to reduce his subjective variability of returns under the new technology, σ_1. In addition, extension contact can reduce some of the fixed costs (search and learning) associated with adoption as reflected in k. Finally, land reform is reflected by a change in farm size L. Given the above preliminaries, it is possible to derive a number of propositions which admit testable hypotheses on the behavior of individual farmers. These propositions focus on technology adoption choices under each of the various policies.

<u>Proposition 1: Price Support</u>. If the new technology pertains to a new crop, then a price support will cause adopting farmers to increase intensity of use of the new technology unless they have already fully adopted or have exhausted their credit (in which case, there is no intensity effect); also, the tendency to adopt is increased among nonadopting farmers for whom credit permits. If the new technology pertains to the existing crop, then a price support will cause adopting farmers to increase intensity of use of the new technology unless they have already fully adopted or have exhausted their credit if the correlation of returns under the two technologies is high ($\rho > \beta_\sigma$) and the expected per hectare gains from adoption are high ($\beta_m < L_1/L_0$). However, intensity of use will decrease in the same case if the correlation of returns if low ($\rho < \beta_\sigma$) and the expected increase in returns per hectare is low (β_m close to 1).

To determine the effects of price support policies, we clearly need data on adopting and nonadopting farmers; the availability of credit across each of these two groups of farmers; and the correlation among the returns under the two technologies. Proposition 1 suggests the price support policies cannot be pursued independently of credit market conditions. In particular, a well-designed price support policy which neglects the availability of credit may not have the intended effect on technological adoption.

<u>Proposition 2: Credit Funding</u>. The effect of a public credit program that increases credit availability at the market interest rate is to increase the intensity of adoption for adopting farmers who have exhausted their credit limit; the intensity of adoption is unaffected for other adopting farmers. In addition, the tendency to adopt among nonadopting farmers increases but only among those for whom credit is initially insufficient to finance adoption.

Proposition 3: Credit Subsidy. The effect of a credit subsidy or public loan guarantee which lowers effective interest rates for farmers is to increase the intensity of adoption among adopting farmers unless they have already fully adopted or exhausted their credit (in which case there is no intensity effect); in addition, the tendency to adopt increases among all nonadopting farmers.

Effective evaluations of credit funding requires data on the profiles of nonadopting farmers, particularly their credit availability and degree of risk aversion. Once again, a combination of policies may prove to be more effective in achieving desired results. The effect of a credit subsidy on lowering the effective cost of capital may be minimal due to the exhaustion of available credit.

Proposition 4: Crop Insurance or Price Stabilization. If the new technology pertains to a new crop, then the effect of actuarially fair crop insurance or mean-preserving price stabilization is to increase the intensity of adoption among adopting farmers unless they have already fully adopted or have exhausted their credit (in which cases there is no intensity effect); in addition, the tendency to adopt is increased among nonadopting farmers for whom credit permits. If the new technology pertains to the existing crop, then among adopting farmers who have not already fully adopted or exhausted their credit, crop insurance or price stabilization causes an increase in the intensity of adoption if the correlation of returns under the two technologies is low ($\rho < \beta_\sigma$), while the intensity decreases if the correlation is high ($\rho > \beta_\sigma$); the intensity of adoption is unaffected for other adopting farmers.

A well-designed crop insurance or price stabilization policy may not have the intended intensity effect unless sufficient financial credit is available. Simply lowering the variability of returns under the new technology through crop insurance or some other means may not have any effect on the rate of adoption.

Proposition 5: Modern Input Subsidy. The effect of a subsidy on the modern input is to increase the intensity of adoption among adopting farmers who have not already fully adopted. In addition, the tendency to adopt increases among all nonadopting farmers except those who have insufficient credit to finance the initial outlay.

Proposition 6: Fixed Cost Subsidy. The effect of a subsidy on the fixed cost of adoption (a one-time subsidy for adoption) is to increase the intensity of adoption among adopting farmers who have not already fully adopted. Also, the tendency to adopt increases among all nonadopting farmers.

As one would expect, the effects of input subsidies or fixed cost subsidies are qualitatively equivalent. Each of these two policies in effect expands the credit constraint and, thus, the intended effects may be more easily accomplished.

Proposition 7: Extension. (a) The effect of extension activities that improve farmers' subjective distributions of returns under the new technology is to cause adopting farmers to increase the intensity of adoption if they have not already fully adopted or exhausted their credit (intensity of adoption for other adopting farmers is unaffected). In addition, the tendency to adopt increases among nonadopting farmers for whom credit permits. (b) The effect of extension activities that reduce perceived search and learning costs connected with adoption is to increase the intensity of adoption among adopting farmers who have not already fully adopted. Also, the tendency to adopt increases among all nonadopting farmers except for those who have insufficient credit to finance the initial unavoidable pecuniary costs.

Effective extension programs can simultaneously operate on the perceived probability distribution of returns under the new technology as well as the transaction cost associated with learning about the effective utilization of the new technology. This latter effect, through the measure of fixed costs, reduces the demand on available credit. Nevertheless, the most effective extension program will not achieve the intended effects if credit is simply unavailable.

Proposition 8: Land Reform. The effect of an increase in land endowment among adopting farmers with nonbinding credit is to increase the intensity of adoption if a farmer is fully adopted (all new land is allocated to the new technology) or if the intensity of adoption is low relative to the correlation of yields among the two technologies and to decrease the intensity of adoption if the intensity of adoption is high relative to the correlation of yields. The effect among adopting farmers with binding credit is to reduce the intensity of adoption since all new land is allocated to the old technology.

Obviously, land reform without corresponding policies related to credit funding, credit subsidies, input subsidies, or fixed cost subsidies may prove to be totally ineffective. Tight credit or its unavailability will, in fact, reduce the adoption rate of the more modern technology under a land reform policy.

4. Equity and Efficiency

To examine distributional issues quantitatively in the context of the above model, a distribution of microparameters among farmers must be specified. The results here focus on the distribution of risk preferences, farm size, and credit availability with the farm(er)s assumed to be identical in other respects. This is done by first specifying a distribution of farm size and then specifying a relationship between farm size and risk preferences and credit.

Suppose the distribution of landholdings follows a Pareto distribution with density function

$$f(L) = (\gamma - 1)^{\gamma} \gamma^{1-\gamma} \bar{L}^{\gamma} L^{-\gamma-1} \text{ for } \frac{\gamma - 1}{\gamma} \bar{L} < L < \infty; \gamma > 1.$$

Note that the average farm size is $\bar{L}$ and that γ is a measure of concentration of the farm size distribution. The effect of a change in farm size concentration holding with average farm size fixed is depicted in Figure 2. As γ increases, the farm size distribution becomes more equitable with both small farms tending to become larger and large farms tending to become smaller.

Given this distribution of farm size, risk preferences as reflected by the coefficient of absolute risk aversion are assumed to be related to initial wealth or farm size following the equation

$$\phi = \tilde{B} W_0^{-\eta} = BL^{-\eta}, \qquad 0 < \eta < 1,$$

where initial wealth is $W_0 = p_L L$ and $B = \tilde{B} p_L^{-\eta}$. Absolute risk aversion is assumed to be constant for each individual farmer; however, $\eta > 0$ implies that larger farmers have less absolute risk aversion and $\eta < 1$ implies that

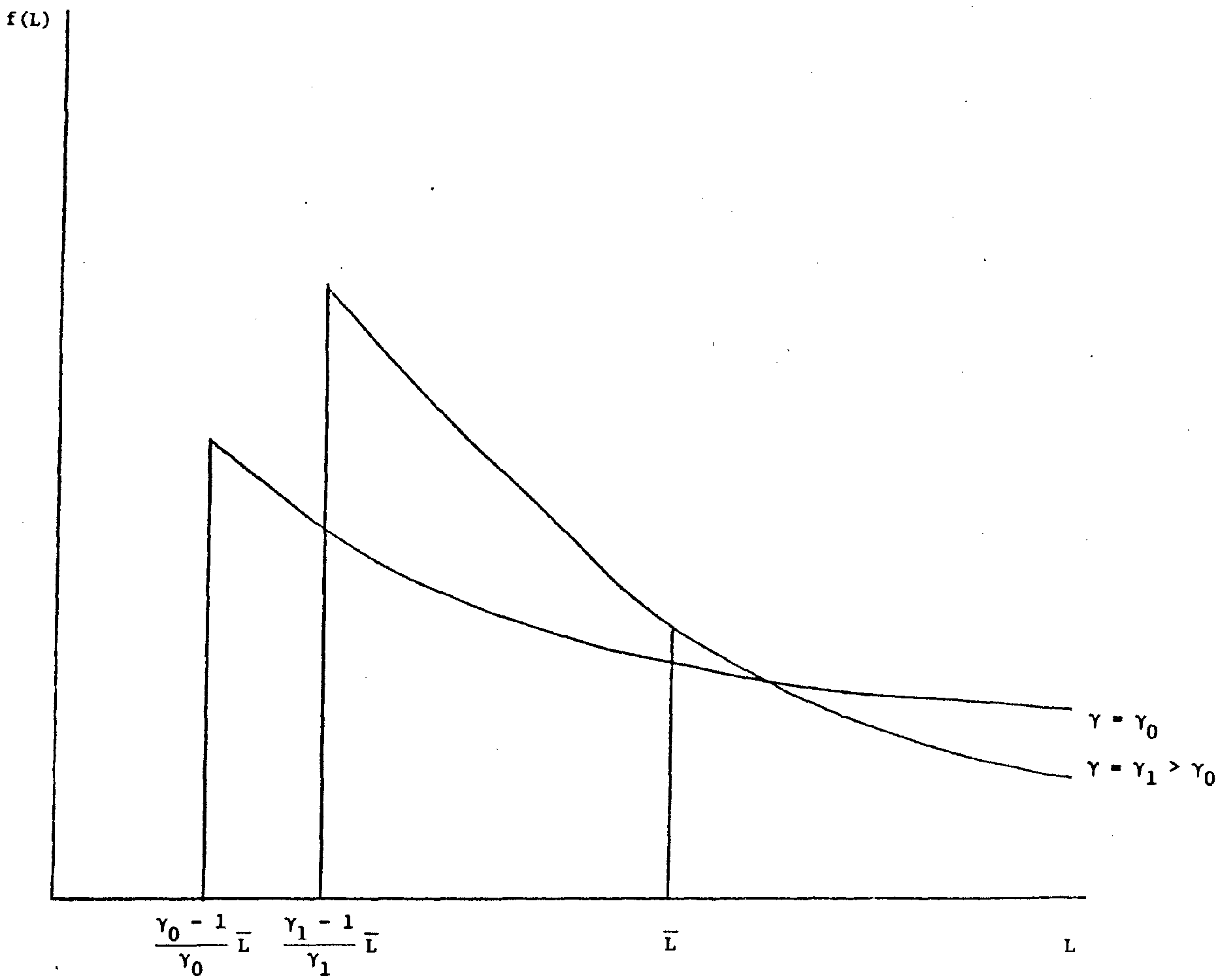

Figure 2

larger farmers have more relative risk aversion following Arrow's arguments. To simplify, the availability of credit is also assumed to be related to initial wealth or, equivalently, farm size, following the equation

$$K = aL.$$

Finally, note that following the assumption of constant absolute risk aversion for individual farmers, one can write

$$U_0(L) = (p_L + m_0) L - \frac{\phi}{2} \sigma_0^2 L^2 \tag{10}$$

$$U_1 (L, L_1) = (p_L + m_0) L + (m_1 - m_0) L_1 - rk$$
$$- \frac{\phi}{2} [\sigma_0^2 (L - L_1)^2 + \sigma_1^2 L_1^2 + 2\rho \sigma_0 \sigma_1 L_1 (L - L_1)]. \tag{11}$$

Using the model of section 3, the relationship of adoption intensity and farm size can be determined as illustrated in Figures 3 and 4. First, the intensity of adoption as measured by L_1 is physically constrained to lie between the lines $L_1 = L$ and $L_1 = 0$. Second, the intensity of adoption is constrained to lie on or below the credit limitation boundary $L_1 = (K - k)/w = (aL - k)/w$. Subject to these limitations, the intensity of adoption given adoption follows L_1^* in (5). Finally, there is a minimum farm size, $\hat{L}_1$, where fixed costs can be adequately spread to make adoption worthwhile.

Note that Figure 3 is drawn to depict the case where the major barriers to adoption are risk aversion and set-up costs. Below farm size $\hat{L}_{11}$, fixed costs cannot be adequately spread to justify adoption. At farm size $\hat{L}_{12}$,

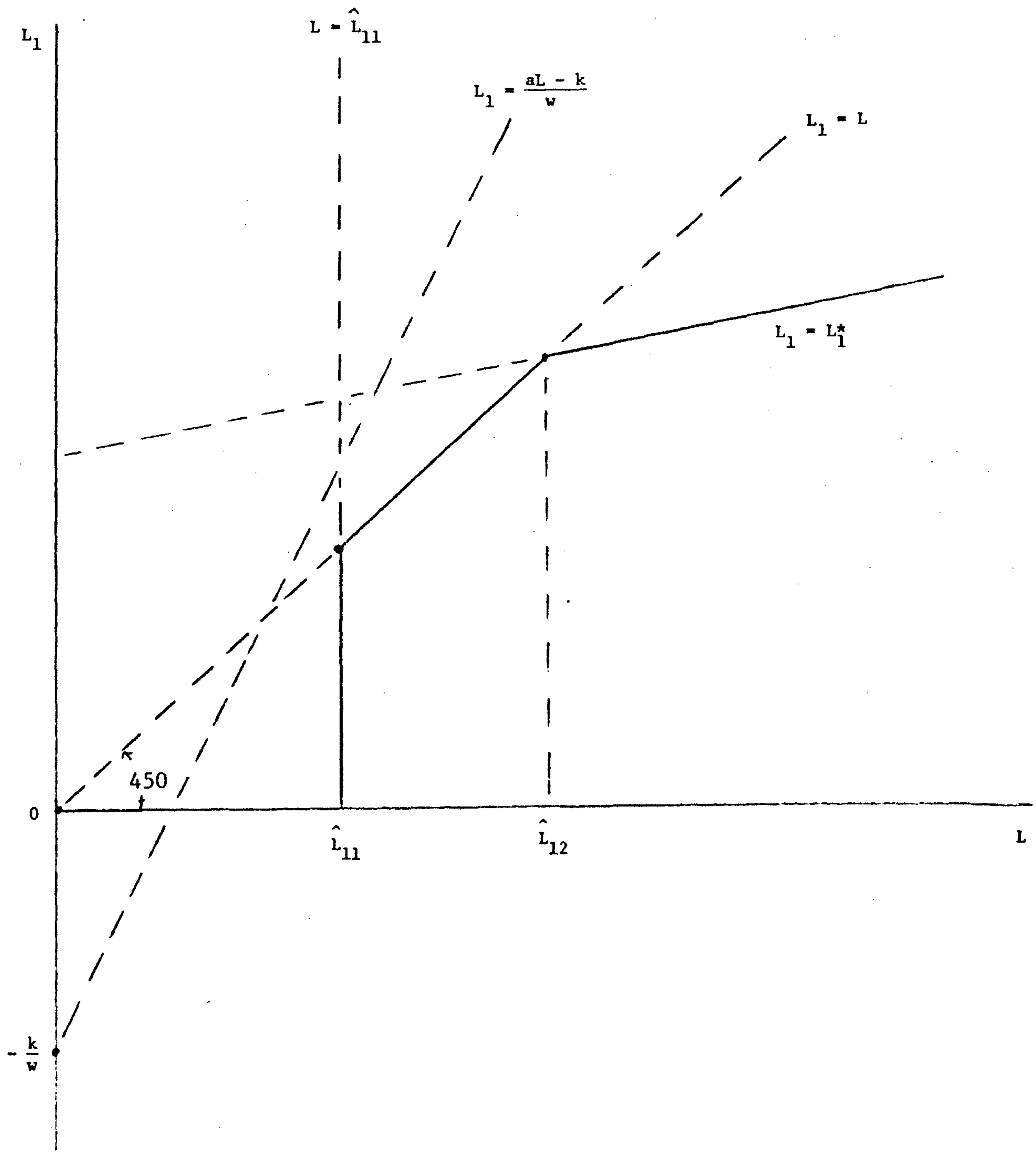

Figure 3

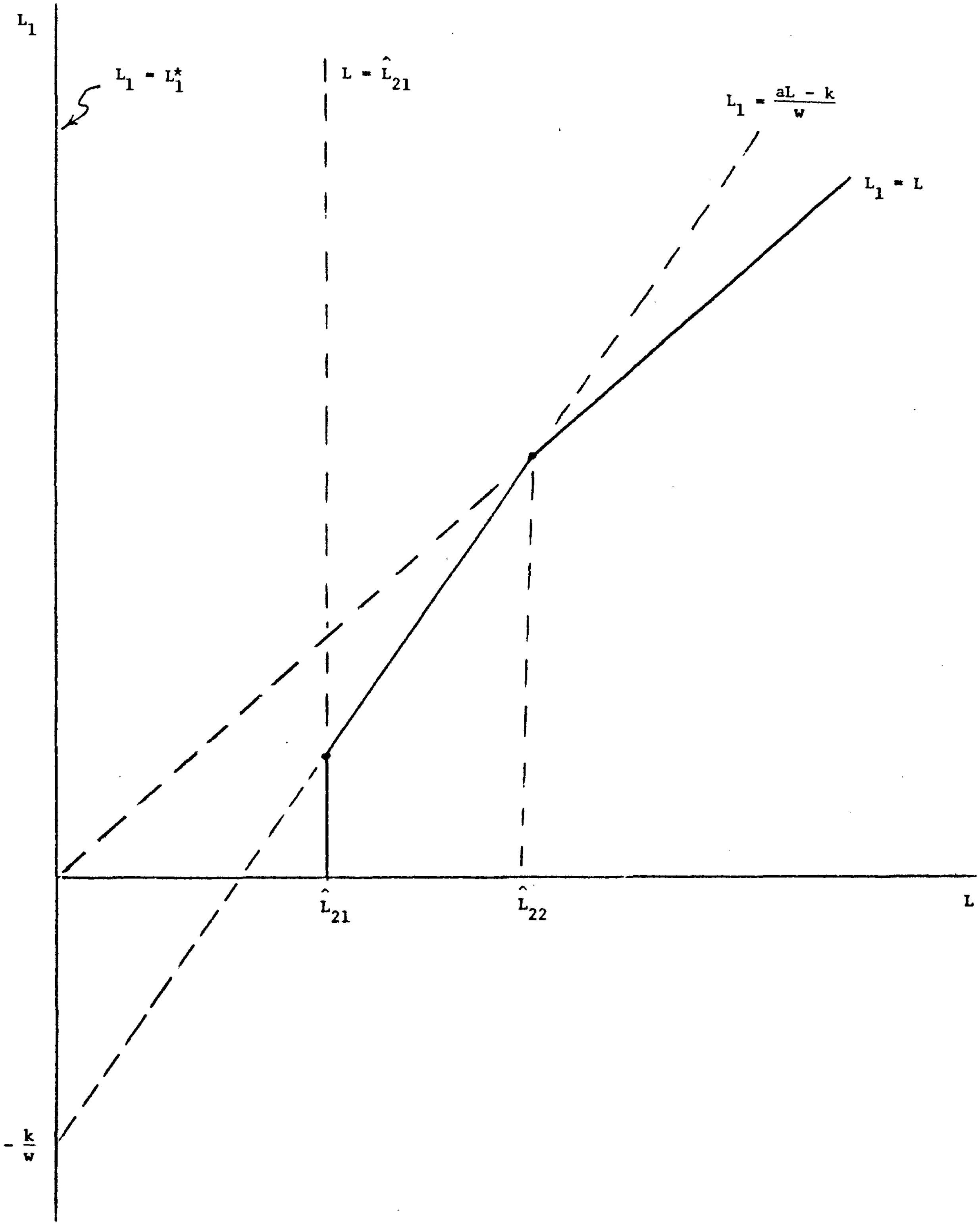

Figure 4

perceived risk becomes sufficiently large to induce diversification. In this case, credit never becomes binding since the credit line $L_1 = (aL - k)/w$ is above the adoption expansion path beyond $\hat{L}_{11}$.

Figure 4 is drawn to depict the case where the major barriers to adoption are credit and set-up costs and farmers are risk neutral. Below farm size $\hat{L}_{21}$, fixed costs cannot be adequately spread to justify adoption. At farm size $\hat{L}_{21}$, adoption becomes desirable but credit limitations prevent full adoption. At farm size $\hat{L}_{22}$, credit becomes nonbinding and allows full adoption.

Of course, many other possibilities in addition to the cases in Figures 3 and 4 exist. For example, Figure 4 is drawn to depict the case of risk neutrality where $L_1 = L_1^*$ becomes vertical at $L = 0$. If risk aversion is introduced in Figure 4, then $L_1 = L_1^*$ rotates downward and intersects $L_1 = L$ as in Figure 3. Thus, another critical point beyond $\hat{L}_{12}$ may occur where farmers switch back to diversification. Also, with higher fixed cost k, the credit line moves downward in a vertically parallel fashion and may eliminate the full adoption segment. Or if credit per hectare, a, is lower, the slope of the credit line is smaller and may eliminate the full adoption segment or even cause credit to become binding for all adopters. Turning to the L_1^* line, one finds with risk aversion that very large farms partially adopt if $0 < R < 1$ (the low correlation case with new technology more risky than old) but farms beyond some critical size (not shown) will not adopt if $R < 0$ (the high correlation case) since L_1^* will have negative slope and eventually intersect $L_1 = 0$. In addition, with lower expected gains, $E(\Delta\pi)$, or higher risk aversion, ϕ, the L_1^* line moves down in parallel fashion and may eliminate the full adoption segment and possibly also the binding credit segment. Finally, several factors such as relative profitability, relative riskiness, risk aversion, credit, and fixed costs can cause the critical point $\hat{L}_1$ at which adoption occurs to move to the right, possibly eliminating the binding credit segment or both the binding credit and full adoption segments.

Since the alternatives presented by these cases are too numerous to analyze here, only two stylized alternatives are considered in the remainder of this paper. Casual observation suggests that many adoption problems involve at least some farmers who fully adopt and some farmers who only partially adopt either because of excessive perceived risk with the new technology or credit limitations. The two cases below focus respectively on these two problems. In the first case, any partial adoption is assumed to be a diversifying response to excessive perceived risk as in Figure 3. In the second case, any partial adoption is assumed to be due to insufficient credit as in Figure 4. For ease of exposition, this case is only considered under the assumption of risk neutrality. In either case, one of the reasons that adoption is a problem is that some farmers are nonadopters; thus, $\hat{L}_0 = \hat{L}_{i0} = (\gamma - 1)/\gamma \, \bar{L} < \hat{L}_{i1}$ is assumed.

Equity and efficiency will be examined by investigating the effects of various policies on the mean and distribution of the expected utility in (10) and (11). Note that, under the assumptions of this section, the quantities in (10) and (11) are certaintly equivalents and are thus measured in money terms and provide a basis for evaluating the welfare effects (compensating or equivalent variation) of policy changes (Just, Hueth, and Schmitz). The average welfare (certainty equivalent) of farmers is:

$$E(\bar{U}_i) = \int_{\hat{L}_{i0}}^{\hat{L}_{i3}} \bar{U}_i\,(L)\ f(L)\ dL \tag{12}$$

where

$$\bar{U}_1(L) = \begin{cases} U_0(L) & \text{if } \hat{L}_{10} \leq L < \hat{L}_{11} \\ U_1(L,\ L) & \text{if } \hat{L}_{11} \leq L \leq \hat{L}_{12} \\ U_1(L,\ L_1^*) & \text{if } \hat{L}_{12} \leq L < \hat{L}_{13} \end{cases} \tag{13}$$

when the major barriers to adoption are risk aversion and set-up costs and

$$\bar{U}_2(L) = \begin{cases} U_0\ (L) & \text{if } \hat{L}_{20} \leq L \leq \hat{L}_{21} \\ U_1\left(L,\ \frac{aL\ -\ k}{w}\right) & \text{if } \hat{L}_{21} \leq L \leq \hat{L}_{22} \\ U_1(L,\ L) & \text{if } \hat{L}_{22} \leq L \leq \hat{L}_{23} \end{cases} \tag{14}$$

when the major barriers to adoption are credit and set-up costs.

A more popular policy performance measure that ignores the welfare effects of risk on farmers is average income,

$$E(Y_i) = \int_{\hat{L}_{i0}}^{\hat{L}_{i3}} Y_i(L)\ f(L)\ dL, \tag{15}$$

where

$$
Y_1(L) = \begin{cases} m_0 L & \text{if } \hat{L}_{10} \leq L \leq \hat{L}_{11} \\ m_1 L - rk & \text{if } \hat{L}_{11} \leq L \leq \hat{L}_{12} \\ m_0 L + (m_1 - m_0) L_1^* - rk & \text{if } \hat{L}_{12} \leq L \leq \hat{L}_{13} \end{cases} \tag{16}
$$

when the major barriers to adoption are risk aversion and set-up costs and

$$
Y_2(L) = \begin{cases} m_0 L & \text{if } \hat{L}_{20} \leq L \leq \hat{L}_{21} \\ m_0 L + E(\Delta\pi) \frac{aL - k}{w} - rk & \text{if } \hat{L}_{21} \leq L \leq \hat{L}_{22} \\ m_0 L + E(\Delta\pi) L_1^* - rk & \text{if } \hat{L}_{22} \leq L \leq \hat{L}_{23} \end{cases} \tag{17}
$$

when the major barriers to adoption are credit and set-up costs.

The popular measure (15) is obviously a misspecification of the welfare measure (12); the magnitude of bias in using (15) in lieu of (12), depends upon the degree of risk aversion. In any event, since (15) is frequently employed in empirical analysis, the propositions derived in this section focus on these performance measure as well as (12). Following the same format as section 3, the propositions reported here focus on aggregate behavior under each of the various policy alternatives.

The propositions in this section are proven in Appendix B by solving for L_{i1} and L_{i2}, performing the integration in (12) and (15), and evaluating the qualitative effects of various policies on the resulting policy performance measures. Note that all results assume no product price effects of adoption. Such effects can be easily introduced but the exposition and understanding of propositions becomes less clear when such effects are introduced. Furthermore, the modifications introduced by such considerations follow intuition.

Proposition 9: Price Support. (a) If the new technology pertains to a new crop, then a price support will cause aggregate farm income to increase by either the expected utility or the expected income criteria. Nonadopters are unaffected by the price support, while full adopters and partial adopters become better off, thus widening the income distribution. Where risk aversion and set-up costs are the major barriers to adoption, the minimum scale required for adoption declines, while the maximum size of fully adopting farms increases; more adoption is thus induced. In the case where credit and set-up costs are the major barriers to adoption, neither the critical levels of adoption nor overall adoption is affected. (b) If the new technology pertains to the existing crop, then a price support will cause an increase in aggregate farm income if the major barriers to adoption are credit and set-up costs. The same result obtains for the low correlation case ($\rho < \sigma_0 \sigma_1$) where the major barriers to adoption are risk aversion and set-up costs. In this case the well-being of every individual farmer is improved according to the expected utility criterion whether or not they are adopters. The same is true of the expected income criterion except for the case of partial adopters with high correlation where the major barriers to adoption are risk aversion and set-up costs. Also, in the case where the major barriers to adoption are risk aversion and set-up costs, the minimum scale required for adoption declines, while the maximum size of fully adopting farms increases and the overall level of adoption increases. In the case where the major barriers to adoption are credit and set-up costs, adoption is unaffected.

As Proposition 9 demonstrates, price support policies will be effective in improving efficiency in some instances and ineffective in others. In addition, the major barriers to adoption--whether credit, set-up costs, or risk aversion--will influence the efficiency response to price support policies.

Proposition 10: Credit Funding. The effect of a public credit program that increases credit availability at the market interest rate is to increase aggregate farm income if credit and set-up costs are the major barriers to adoption, while expected income is unaffected if risk aversion and set-up costs are the barriers to adoption. If credit and set-up costs are the major barriers to adoption, then nonadopters and full adopters are unaffected, while the well-being of partial adopters is increased; the minimum scale required for both partial adoption and full adoption is decreased so that overall adoption increases.

Without knowledge of the nature of barriers to adoption, credit funding policies can be indeed precarious. In some instances small, nonadopting farmers can be unaffected by credit funding policies.

Proposition 11: Credit Subsidy. The effect of a credit subsidy or public loan guarantee, which lowers effective interest rates for farmers, is to increase aggregate farm income. Nonadopters are not affected, while both partial adopters and full adopters are made better off. In the case where the major barriers to adoption are risk aversion and set-up costs, the minimum scale required for adoption declines, while the maximum size of fully adopting farms increases and overall adoption increases. In the case where credit and set-up costs are the major barriers to adoption, adoption is unaffected.

Once again, we see that the effectiveness of a particular policy crucially depends on the structure of barriers to adoption. The effect of credit subsidies on the mininum scale for adoption, as well as the maximum scale for full adoption, is particularly revealing and can provide much insight to policymakers attempting to influence both efficiency and equity.

Proposition 12: Crop Insurance or Price Stabilization. (a) If the new technology pertains to a new crop, then the effect of actuarially fair crop insurance or mean-preserving price stabilization is to improve aggregate farm income if the major barriers to adoption are risk aversion and set-up costs, while farmer welfare is unaffected if the major barriers to adoption are credit and set-up costs. All farmers, whether adopting or not, benefit in the former case. Also in the former case, the minimum scale required for adoption declines, while the maximum size of fully adopting farms increases so that overall adoption increases. (b) If the new technology pertains to the existing crop, then the effect of actuarially fair crop insurance for mean-preserving price stabilization is to improve aggregate farm income according to the expected utility criterion if the major barriers to adoption are risk aversion and set-up costs, while farmer well-being is unaffected in the case where the major barriers to adoption are credit and set-up costs. However, according to the expected income criterion, the average well-being of farmers improves only in the case with high correlation ($\rho > \beta_\sigma$), while the average well-being of farmers declines in the low correlation case ($\rho < \beta_\sigma$). In the case where the major barriers to adoption are risk aversion and set-up costs, the well-being of each individual farmer improves according to the expected utility criterion; but only the large partial-adopting farmers are affected according to the expected income criterion. The welfare of these farmers is improved in the case of high correlation and adversely affected in the case of low correlation. Also, in the case where the major barriers to adoption are risk aversion and set-up costs, the minimum scale required for adoption is decreased, while the maximum size of fully adopting farms is increased so overall adoption increases.

Proposition 12 clearly reveals that pursuit of insurance or price stabilization schemes will not be effective in all instances. One means of assuring their effectiveness is to combine such policies with credit-related policies to relieve a potentially important barrier to adoption. In addition, for insurance policies, correlation among returns assumes critical importance.

Proposition 13: Modern Input Subsidy. The effect of a subsidy on the modern input is to increase aggregate farm income. Nonadopting farmers are unaffected, while the welfare of both fully adopting and partially adopting farmers is improved. In the case where risk aversion and set-up costs are the major barriers to adoption, the minimum scale required for adoption decreases, while the maximum size of fully adopting farms is increased so that overall adoption increases. In the case where the major barriers to adoption are credit and set-up costs, the minimum scale required for adoption is unaffected, while the minimum size of fully adopting farms decreases so that overall adoption increases.

Once again, the effectiveness of a modern input subsidy depends on the nature of adoption barriers. Only by combining credit policies with modern input subsidies would it be possible to insure that smaller farmers benefit.

Proposition 14: Fixed Cost Subsidy. The effect of a subsidy on the fixed cost of adoption (a one-time subsidy for adoption) is to increase the aggregate welfare of farmers. Small nonadopting farms are unaffected, while the welfare of larger fully and partially adopting farmers increases. The minimum scale required for adoption declines. The maximum size of fully adopting farms is unaffected in the case where the major barriers to adoption are risk aversion and set-up costs, while the minimum scale associated with full adoption declines in the case where credit and set-up costs are the major barriers to adoption. Overall adoption increases in either case.

A fixed-cost subsidy strikes at the credit and set-up cost barriers to adoption that are faced by small farms. Hence, the equity implications of this particular policy may be more desirable than other policies.

Proposition 15: Extension. The effect of extension activities that improve farmers' subjective distributions of returns under the new technology or that reduce perceived search and learning costs connected with adoption is to increase average expected farmer welfare and the overall level of adoption. These increases are shared by larger farms with sufficient scale for adoption, while farms below the minimum scale required for economical adoption are unaffected.

The efficiency effects of extension policies are as expected. Note that to influence the equity outcomes of extension policies, however, integration with other instruments may be required. Only by combining extension programs with other policies is it safe to infer that the minimum scale required for adoption will be decreased.

The above propositions, in context of the six classes of farmers identified by (13) and (14), reveal the varying qualitative effects that can be achieved by different policies. They demonstrate the importance of different types of barriers to adoption and, perhaps more importantly, the need to operate with more than a single policy regime. In other words, positive equity effects can be achieved more readily by operating with a mix of policies rather than a single policy.

Propositions 9 through 15 focus on the efficiency effects of various policies. However, these propositions, along with the derivations in Appendix B, also provide the needed results to sort out the efficiency effects of various policies. In this regard, Table 6 appearing in Appendix B is particularly relevant. This table records the efficiency effects of various policies decomposed by class of farmers. Farm size within each of the behavioral groups is unaffected by some policies and strongly influenced by others. For example, policies that impinge on the mean return of the modern technology (price supports, extension programs) have no effect on the welfare of small nonadopting farmers, a unitary effect on partial adopting farmers, and a less than unity effect on full adopters in the case where the major barriers to adoption are risk aversion and set-up cost. In the case where the major barriers to adoption are credit and set-up costs, once again, we have no effect on a small nonadopting farms, a greater than unity effect on partial adopting farms, and unitary effect on full adopting.[2]

5. Conclusion

The focus of this paper is on the qualitative efficiency and equity effects of various policies. In the context of a simple theoretical model which incorporates a number of important features of the economic environment found in less-developed countries, propositions have been derived which reveal many insights for actual policy analysis. However, to operationalize these propositions, a fair amount of empirical estimation is required.

Empirical analysis must begin by decomposing the farming population into relevant classes. This decomposition can be accomplished endogenously by the specification of a discrete/continuous behavioral model. The discrete choice relates to technology, while the continuous choice is the amount of land allocated across technologies. Available secondary data can be employed by a simultaneous discrete/choice model of farmer behavior (Hanemann). The explanatory variables appearing in this model include vector of expected returns defined by technology, the variances and covariances of returns defined across technologies, variable cost of modern inputs, the opportunity cost of financial funds, fixed set-up costs of various technologies, and available credit.

Estimated relationships between the above explanatory variables and discrete technology choices and continuous land allocation choices is one component of the required empirical structure. A second component is an estimation of the distribution of landholdings. One potential distribution is the Pareto distribution specified in section 4. A third empirical component must relate the distribution of farm size to risk preferences. Estimation of this relationship will most likely require the use of primary data from representative samples. The final empirical component requires a set of linking equations between the policy instruments and the specified explanatory variables. For example, the empirical relationship between price supports and the vector of mean returns and the covariance matrix of returns across technologies must be determined.

Armed with the above four empirical components, a number of operational uses of the proposed framework are possible. First, we can simply simulate the effects of various policies through the four empirical components to determine the most effective integration of the various policies. This potential use of an empirical version of the proposed framework can only capture the quantitative effect of the proposed policy mixes. No attempt would be made to identify the optimal set of policies.

The specification of a formal criterion function would allow the search for the optimal set of policies. Various trade-off relationships or alternative weightings in a scalar criterion function including two principal performance measures, efficiency and equity, could be specified. Theory and intuitive reasoning can be heavily utilized in isolating those tradeoffs which allow a set of scalar criterion functions to be examined by parametric analysis. When such critierion functions cannot be captured, again, parametric analysis can be utilized with some objectives expressed as constraints motivated perhaps by a lexicographic ordering and/or as satisficing arguments. Various solution algorithms that can be employed to enhance the determination of a global optimum are available (Rausser, Just, and Zilberman).

Another potential use of the four empirical components relates to the notion of political economic markets. In a positive analysis of government behavior, the four components can represent a constraint structure which, along with a specified criterion function, can be used to infer via revealed preference methodology the trade-off between efficiency and equity (Rausser). Such a positive analysis would allow economic researchers to effectively perform a role of social critics; that is, if past policies imply a value scheme which in some sense deviates from the public interest, then the implicit choice of tradeoffs between efficiency and equity should at least be debated. Along similar lines, various economic interest groups could also employ the four empirical components to determine which set of policies they are prepared to support or oppose.

In the final analysis, the proposed theoretical framework and its empirical counterpart will prove to be a valuable element in the tool kit of policy analysts if and only if sound data support systems are designed and maintained. The required data support system for the proposed framework is indeed demanding. Nevertheless, it is our view that the expected benefits from designing and maintaining such a data support system far outweigh its associated cost. It is our hope that required data support system can be employed via the proposed framework to determine egalitarian development strategies (involving an integration of various policies) which significantly alters distribution of wealth and landholdings within the agricultural production systems of less-developed countries.

Appendix A

Using equation (4), this appendix derives the properties of the optimal solution to (3) as functions of the control variables, m_1, σ_1, w, K, k, r, and L. For these purposes, assume

$\phi > 0$

$\sigma_0^2 + \sigma_1^2 - 2\rho\sigma_0\,\sigma_1 > 0$

$m_0 = \beta_m\, m_1 < m_1$

$\sigma_0 = \beta_\sigma\, \sigma_1 \leq \beta_m\, \sigma_1$

$\rho \geq 0$

$0 \leq \eta \equiv - \phi'\, \overline{W}/\phi \leq 1.$

Note that η is elasticity of risk aversion. As shown by Just and Zilberman, $\eta \geq 0$ corresponds to nondecreasing absolute risk aversion and $\eta \leq 1$ corresponds to nonincreasing relative risk aversion.

Under the assumption of full utilization of land ($L_0 + L_1 = L$), the problem in (3) can be rewritten as

$$\max_{L \geq L_1 \geq 0} \quad EU[(p_L + \pi_0)\, L + (\pi_1 - \pi_0)\, L_1 - rk] \tag{A1}$$

subject to

$$k + wL_1 \leq K.$$

Just, Zilberman, and Rausser show that the objective function in (A1) is strictly concave. Thus, the optimum must either be attained internally and be equivalent to the unconstrained optimum or the optimum must be attained at one of the points where constraints are binding. The first-order condition for maximization of the unconstrained problem is

$$\frac{dEU}{dL_1} = E[U'(\pi_1 - \pi_0)] = 0$$

and, as shown by Just and Zilberman, is approximated by

$$E(\Delta\pi) - \phi[L_1 V(\Delta\pi) + L(\rho\sigma_0 \sigma_1 - \sigma_0^2)] = 0 \tag{A2}$$

The solution, L_1^*, is given by (5) using (6)-(9). Thus, based on the graphical argument related to Figure 1, the solution to the constrained problem is given by (4).

From (A2), second-order conditions require

$$- \phi V(\Delta\pi) \left[1 - \eta \frac{E(\Delta\pi)}{\phi L V(\Delta\pi)} \frac{L E(\Delta\pi)}{\bar{W}}\right] < 0.$$

To see that this condition holds, note that $L_1 \leq L$ implies from (5) that any internal solution must satisfy

$$\frac{E(\Delta\pi)}{\phi L V(\Delta\pi)} \leq 1 - R = \frac{1}{1 + \frac{\sigma_0(\sigma_0 - \rho\sigma_1)}{\sigma_1(\sigma_1 - \rho\sigma_0)}} \leq \frac{\sigma_1}{\sigma_1 - \sigma_0} \leq \frac{1}{1 - \beta_m} .$$

Hence,

$$D = 1 - \eta \frac{E(\Delta\pi)}{\phi L V(\Delta\pi)} \frac{L E(\Delta\pi)}{\bar{W}} \geq 1 - \eta \frac{m_1 \bar{L}}{\bar{W}} \geq 0 \tag{A3}$$

assuming perceived average income is less than expected wealth at the end of the production period (which includes perceived income).

Because of the nature of the solution in (4), the effects of the controls tend to differ according to the four conditions in the right-hand side of (4). Thus, for simplified notation, let the case of a lower bound (LB) solution denote $L_1^* < 0$ or $k > K$; let the case of an internal solution (IS) denote $0 \leq L_1^* \leq L$ and $(K - k)/w > 0$; and let the case of a binding credit (BC) solution denote $L \geq L_1^* > (K - k)/w > 0$; and let the case of an upper bound (UB) solution denote $(K - k)/w > L$ and $L_1^* > L$.

Using (4) and (A3), one finds

$$\frac{dL_1}{dm_1} = \begin{cases} \frac{1}{\phi DV(\Delta\pi)} \left[1 + \eta\, L_1 \frac{E(\Delta\pi)}{\bar{W}}\right] > 0 & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \tag{A4}$$

$$\frac{dL_1}{d\sigma_1} = \frac{dL_1}{d\bar{\sigma}} = \begin{cases} -\frac{1}{DV(\Delta\pi)} [L_1\, (2\sigma_1 - \rho\sigma_0) + L\, \rho\sigma_0] < 0 & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \tag{A5}$$

$$\frac{dL_1}{dw} = \begin{cases} -\frac{(1 + r)\, L_1}{\phi DV(\Delta\pi)} \left[1 + \eta \frac{E(\Delta\pi)}{\bar{W}}\right] < 0 & \text{if IS} \\ -\frac{K - k}{w^2} < 0 & \text{if BC} \\ 0 & \text{if LB or UB} \end{cases} \tag{A6}$$

$$\frac{dL_1}{dK} = \begin{cases} \frac{1}{w} > 0 & \text{if BC} \\ 0 & \text{if IS, LB, or UB} \end{cases} \tag{A7}$$

$$\frac{dL_1}{dk} = \begin{cases} -\frac{\eta r \, E(\Delta\pi)}{\phi D \, \bar{W} \, V(\Delta\pi)} < 0 & \text{if IS} \\ -\frac{1}{w} < 0 & \text{if BS} \\ 0 & \text{if LB or UB} \end{cases} \tag{A8}$$

$$\frac{dL_1}{dr} = \begin{cases} -\frac{w \, L_1 \, \bar{W} + \eta k \, E(\Delta\pi)}{\phi D \bar{W} \, V(\Delta\pi)} < 0 & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \tag{A9}$$

$$\frac{dL_1}{dL} = \begin{cases} \frac{R}{D} + \eta \frac{1}{D} \frac{p_L + m_0}{\bar{W}} \frac{E(\Delta\pi)}{\phi V(\Delta\pi)} & \text{if IS} \\ 1 & \text{if UB} \\ 0 & \text{if LB or BC} \end{cases}$$

$$\doteq \begin{cases} \frac{1}{D} \left[(1 - \eta) R + \eta \frac{L_1}{L} \right] \gtreqless 0 \text{ as } R \gtreqless \frac{\eta}{\eta - 1} \frac{L_1}{L} & \text{if IS} \\ 1 & \text{if UB} \\ 0 & \text{if LB or BC} \end{cases} \tag{A10}$$

$$\frac{dL_1}{dm_0} = \begin{cases} -\frac{1}{\phi DV(\Delta\pi)}\left[1 + \eta\,\frac{(L - L_1)\;E\;(\Delta\pi)}{\bar{W}}\right] < 0 & \text{if IS} \\ \\ 0 & \text{if LB, BC, or UB} \end{cases} \tag{A11}$$

$$\frac{dL_1}{d\sigma_0} = \begin{cases} \frac{2\sigma_0 - \rho\sigma_1}{DV(\Delta\pi)}\,(L - L_1) \gtreqless 0 \text{ as } \rho \lesseqgtr 2\,\frac{\sigma_0}{\sigma_1} & \text{if IS} \\ \\ 0 & \text{if LB, BC, or UB} \end{cases} \tag{A12}$$

$$\frac{dL_1}{d\bar{p}} = \begin{cases} \frac{dL_1}{dm_1}\,\frac{dm_1}{d\bar{p}} + \frac{dL_1}{d\sigma_1}\,\frac{d\sigma_1}{d\bar{p}} \geq 0 & \text{if IS} \\ \\ 0 & \text{if LB, BC, or UB} \end{cases} \tag{A13}$$

$$\frac{dL_1}{d\tilde{p}} = \begin{cases} \left[\frac{dL_1}{dm_1} + \frac{dL_1}{dm_0}\beta_m\right]\frac{dm_1}{d\tilde{p}} + \left[\frac{dL_1}{d\sigma_1} + \frac{dL_1}{d\sigma_0}\beta_\sigma\right]\frac{d\sigma_1}{d\tilde{p}} & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \qquad \text{(A14)}$$

$$\frac{dL_1}{d\tilde{\sigma}} = \begin{cases} \left[\frac{dL_1}{d\sigma_1} + \frac{dL_1}{d\sigma_0}\beta_\sigma\right]\frac{d\sigma_1}{d\tilde{\sigma}} \gtreqless 0 \text{ as } \rho \lesseqgtr \beta_\sigma & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \qquad \text{(A15)}$$

where (A10) follows from (9) assuming $[E(\Delta\pi)\, L_1 - rk]/W$ is near zero, i.e., the expected change in wealth after one period is small relative to total expected wealth.

Note that definite results are obtained in all cases except (A14) where, in the case of IS,

$$\frac{dL_1}{d\tilde{p}} = \frac{1}{\phi DV(\Delta\pi)}\left[1 - \beta_m + \eta\,\frac{E(\Delta\pi)}{\bar{W}}\,(L_1 - \beta_m L_0)\right]\frac{dm_1}{d\tilde{p}_0}$$

$$- \frac{1}{DV(\Delta\pi)}\left[(2\sigma_1 - \rho\sigma_0)\, L_1 + \rho\sigma_0\, L - \beta_\sigma\,(2\sigma_0 - \rho\sigma_1)\, L_0\right]\frac{d\sigma_1}{d\tilde{p}_0}\,.$$

The second component in brackets in the second term has the same sign as $\rho - \beta_\sigma$ as obtained in (A15). The first term is clearly positive if $\beta_m < L_1/L_0$. On the other hand, if β_m gets close to 1, then the first term becomes negative if $\beta_m > L_1/L_0$. Furthermore, if β_m is close to one, then the expected gain from adoption is small while variability increases with adoption so L_1/L_0 tends to be low, i.e., $\lim_{\beta_m \to 1} L_1/L_0 = 0$. Thus, $dL_1/d\tilde{p} > 0$ if $\rho > \beta_\sigma$ and $\beta_m < L_1/L_0$ while $dL_1/d\tilde{p} < 0$ if $\rho < \beta_\sigma$ and $\beta_m \to 1$.

Appendix B

This appendix proves Propositions 9-15. First, note from (4) and (13) where $\phi = BL^{-\eta}$ that

$$L_{12} = \left[\frac{E(\Delta\pi)}{B(\sigma_1^2 - \rho\sigma_1\sigma_0)}\right]^{\frac{1}{1-\eta}} \quad \text{(B1)}$$

and $\hat{L}_{11}$ is obtained by solving

$$E(\Delta\pi)\hat{L}_{11} - \frac{1}{2}\hat{B}L_{11}^{2-\eta}(\sigma_1^2 - \sigma_0^2) - rk = 0. \quad \text{(B2)}$$

for the case where the major barriers to adoption are risk aversion and set-up costs $[U_0(\hat{L}_{11}) = U_1(\hat{L}_{11}, \hat{L}_{12})$ and $U_1(\hat{L}_{11}, \hat{L}_{11}) = U_1(\hat{L}_{11}, \hat{L}_1^*)]$ and from (4) and (14) that

$$\hat{L}_{21} = \frac{k}{a} \quad \text{(B3)}$$

$$\hat{L}_{22} = \frac{k}{a - w} \quad \text{(B4)}$$

under risk neutrality ($\phi = 0$) for the case where the major barriers to adoption are credit and set-up costs $\{U_0(\hat{L}_{21}) = U_1[\hat{L}_{21}\ (a\hat{L}_{21} - k)/w]$ and $U_1[\hat{L}_{21}, (a\hat{L}_{21} - k)/w] = U_1\ (\hat{L}_{21}\ \hat{L}_{21})\}$. In this context,

$$E(\overline{U}_i) = \sum_{j=1}^{3} \int_{\hat{L}_{i,j-1}}^{\hat{L}_{i,j}} \overline{U}_i(L)\, f(L)dL$$

$$= \sum_{j=1}^{3} \sum_{n=0}^{3} - \frac{a_{ijn} A}{\xi(n)} \hat{L}_{i,j-1}^{\xi(n)} - \hat{L}_{ij}^{\xi(n)} \qquad \text{(B5)}$$

where

$$\xi(0) = -\gamma, \quad \xi(1) = \eta - \gamma, \quad \xi(2) = 1 - \gamma, \quad \xi(3) = \eta - \gamma - 2$$

$$A = (\gamma - 1)^{\gamma} \gamma^{1-\gamma} \underline{L}^{\gamma}$$

and

$$\overline{U}_i(L) = \overline{U}_{ij}(L) \equiv a_{ijo} + a_{ij1}L^{\eta} + a_{ij2}L + a_{ij3} L^{2-\eta} \text{ for } L \in \mathcal{S}_{ij} \equiv (\hat{L}_{i,j-1}, \hat{L}_{i,j}) \qquad \text{(B6}$$

with a_{ijn} given in Table 1 and $\hat{L}_{i3} = \infty$ for notational simplicity.

Table 2 is derived by differentiation of the elements of Table 1 with respect to the various policies. Table 3 then derives the marginal effects of various policies on the expected utilities of nonadopting, fully adopting, and partially adopting farmings using equaton (B6) and Table 2, i.e.,

$$\frac{\partial \overline{U}_{ij}(L)}{\partial y} = \frac{\partial a_{ijo}}{\partial y} + \frac{\partial a_{ij1}}{\partial y} L^{\eta} + \frac{\partial a_{ij2}}{\partial y} L + \frac{\partial a_{ij3}}{\partial y} L^{2-\eta}$$

where $y = m_1, \sigma_1 \ldots, \tilde{\sigma}$. Table 4 examines the marginal effects of various policies on the critical farm sizes where switches take place between nonadoption, full adoption, and partial adoption using equations (B1)-(B-4). Table 5 investigates the marginal efficiency effects of various policies by differentiating the overall expected utility in (B5) using Table 3 and Liebniz' rule, i.e.,

TABLE 1

Farm size/ case	Coefficient			
	a_{ij0}	a_{ij1}	a_{ij2}	a_{ij3}
$\mathcal{S}_{11}$	0	0	$p_L + m_0 > 0$	$-\frac{B}{2}\sigma_0^2 < 0$
$\mathcal{S}_{12}$	$-rk < 0$	0	$p_L + m_1 > 0$	$-\frac{B}{2}\sigma_1^2 < 0$
$\mathcal{S}_{13}$	$-rk < 0$	$\frac{E^2(\Delta\pi)}{2B\,V(\Delta\pi)} > 0$	$m_0\,(1 - R_v) + m_1 R_v + p_L > 0$	$-\frac{B\sigma_0^2\,\sigma_1^2\,(1 - \rho^2)}{2V(\Delta\pi)} < 0$
$\mathcal{S}_{21}$	0	0	$p_L + m_0 > 0$	0
$\mathcal{S}_{22}$	$-rk - E(\Delta\pi)\,\frac{k}{w} < 0$	0	$p_L + m_0 + E(\Delta\pi)\,\frac{a}{w} > 0$	0
$\mathcal{S}_{23}$	$-rk < 0$	0	$p_L + m_1 > 0$	0
Coefficient of	1	L^{η}	L	$L^{2-\eta}$

TABLE 2

	$\frac{\partial X}{\partial Y}$	y										
		m_1	σ_1	w	a	k	r	m_0	σ_0	$\bar{p}$	$\tilde{p}$	$\tilde{\sigma}$
	a_{112}	a/						1			$\beta_m \frac{dm_1}{d\tilde{p}}$	
	a_{113}								$-B\sigma_0$		$-B\sigma_0\beta_\sigma \frac{d\sigma_1}{d\tilde{p}}$	$-B\sigma_0\ \beta_0 \frac{d\sigma_1}{d\tilde{\sigma}}$
	a_{120}					$-r$	$-k$					
	a_{122}	1		$-(1 + r)$			$-w$			$\frac{dm_1}{d\bar{p}}$	$\frac{dm_1}{d\tilde{p}}$	
	a_{123}		$-B\sigma_1$							$-B\sigma_1 \frac{d\sigma_1}{d\bar{p}}$	$-B\sigma_1 \frac{d\sigma_1}{d\tilde{p}}$	$-B\sigma_1 \frac{d\sigma_1}{d\tilde{\sigma}}$
OX	a_{130}					$-r$	$-k$					
	a_{131}	$\frac{2a_{131}}{E(\Delta\pi)}$	$\frac{2a_{131}}{\sigma_1}(R_v - 1)$	$-2a_{131}\frac{(1 + r)}{E(\Delta\pi)}$			$-\frac{2a_{131}w}{E(\Delta\pi)}$	$-\frac{2a_{131}}{E(\Delta\pi)}$	$-\frac{2a_{131}R_v}{\sigma_0}$	Z_1	Z_2	Z_6
	a_{132}	R_v		$-(1 + r)\ R_v$			$-wR_v$	$1 - R_v$		$R_v \frac{dm_1}{d\bar{p}}$	Z_3	
	a_{133}		$\frac{2a_{133}\ R_v}{\sigma_1}$						$2a_{133}\frac{1 - R_v}{\sigma_0}$	$\frac{2a_{133}\ R_v}{\sigma_1}\frac{d\sigma_1}{d\bar{p}}$	Z_4	Z_7
	a_{212}							1			$\beta_m \frac{dm_1}{d\tilde{p}}$	
	a_{220}	$-\frac{k}{w}$		$\frac{k - a_{220}}{w}$		$\frac{a_{220}}{k}$		$\frac{k}{w}$		$-\frac{k}{w}\ \frac{dm_1}{d\bar{p}}$	$\frac{k}{w}(\beta_m - 1)\frac{dm_1}{d\tilde{p}}$	
	a_{222}	$\frac{a}{w}$		$\frac{(a_{220} - k)\ a}{kw}$	$\frac{E(\Delta\pi)}{w}$		$-a$	$1 - \frac{a}{w}$		$\frac{a}{w}\frac{dm_1}{d\bar{p}}$	Z_5	
	a_{230}					$-r$	$-k$					
	a_{232}	1		$-(1 + r)$			$-w$			$\frac{dm_1}{d\bar{p}}$	$\frac{dm_1}{d\tilde{p}}$	

(Continued on next page.)

TABLE 2 continued.

a/ Blanks indicate zero.

$$Z_1 = 2a_{131}\left[\frac{1}{E(\Delta\pi)}\frac{dm_1}{d\tilde{p}} + \frac{R_v - 1}{\sigma_1}\frac{d\sigma_1}{d\tilde{p}}\right] > 0$$

$$Z_2 = \frac{2a_{131}}{E(\Delta\pi)}(1 - \beta_m)\frac{dm_1}{d\tilde{p}} + 2a_{131}\left[\frac{R_v - 1}{\sigma_1} - \beta_\sigma\frac{R_v}{\sigma_0}\right]\frac{d\sigma_1}{d\tilde{p}} > 0 \text{ if } R_v > 0$$

$$Z_3 = [R_v + \beta_m(1 - R_v)]\frac{dm_1}{d\tilde{p}} > 0 \text{ if } R_v > 0$$

$$Z_4 = 2a_{133}\left[\frac{R_v}{\sigma_1} + \beta_\sigma\frac{1 - R_v}{\sigma_0}\right]\frac{d\sigma_1}{d\tilde{p}} > 0 \text{ if } R_v > 0$$

$$Z_5 = \left[\frac{a}{w} + \beta_m\left(1 - \frac{a}{w}\right)\right]\frac{dm_1}{d\tilde{p}}$$

$$Z_6 = 2a_{131}\left[\frac{R_v - 1}{\sigma_1} - \beta_\sigma\frac{R_v}{\sigma_0}\right]\frac{d\sigma_1}{d\tilde{\sigma}} < 0 \text{ if } R_v > 0$$

$$Z_7 = 2a_{133}\left[\frac{R_v}{\sigma_1} + \beta_\sigma\frac{1 - R_v}{\sigma_0}\right]\frac{d\sigma_1}{d\tilde{\sigma}} > 0 \text{ if } R_v > 0.$$

TABLE 3[a]

	$\frac{\partial \bar{U}_{ij}(L)}{\partial Y}$	$\bar{U}_{11}$	$\bar{U}_{12}$	$\bar{U}_{13}$	$\bar{U}_{21}$	$\bar{U}_{22}$	$\bar{U}_{23}$
	m_1	[b]	$L > 0$	$L_1^* > 0$		$L_1 > 0$	$L > 0$
	σ_1		$-\beta\sigma\, L^{2-\eta} < 0$	X_2 [c]			
	w		$-(1 + r)\, L < 0$	$-(1 + r)\, L_1^* < 0$		$-L_1\left[1 + r + \frac{E(\Delta\pi)}{w}\right] < 0$	$-(1 + r)\, L < 0$
	a					$\frac{E(\Delta\pi)}{w}\, L$	
	k		$-r < 0$	$-r < 0$		$-r - \frac{E(\Delta\pi)}{w} < 0$	$-r < 0$
y	r		$-k - wL < 0$	$-k - wL_1^* < 0$		$-K < 0$	$-k - wL < 0$
	m_0	$L > 0$		$-L_1^* + L \geq 0$	$L > 0$	$L - L_1 > 0$	
	σ_0	$-B\sigma_0\, L^{2-\eta} < 0$		X_3 [c]			
	$\bar{p}$		$L \frac{dm_1}{d\bar{p}} - B\sigma_1 L^{2-\eta} \frac{d\sigma_1}{d\bar{p}} > 0$	$X_4 > 0$ [d]		$K \frac{dm_1}{d\bar{p}} > 0$	$L \frac{dm_1}{d\bar{p}} > 0$
	$\tilde{p}$	$X_1 > 0$	$L \frac{dm_1}{d\tilde{p}} - B\sigma_1\, L^{2-\eta} \frac{d\sigma_1}{d\tilde{p}} > 0$	$X_5 > 0$	$\beta_m L \frac{dm_1}{d\tilde{p}} > 0$	$[K(1 - \beta_m) + \beta_m L] \frac{dm_1}{d\tilde{p}} > 0$	$L \frac{dm_1}{d\tilde{p}} > 0$
	$\tilde{\sigma}$	$-B\sigma_0\, \beta_\sigma\, L^{2-\eta} \frac{d\sigma_1}{d\tilde{\sigma}} < 0$	$-B\sigma_1\, L^{2-\eta} \frac{d\sigma_1}{d\tilde{\sigma}} < 0$	$X_6 < 0$			

(Continued on next page.)

TABLE 3 continued.

a/ Definitions of X_i are as follows:

$$X_1 = \beta_m \, L \, \frac{dm_1}{d\tilde{p}} - B\sigma_0 \, \beta_\sigma \, L^{2-\eta} \frac{d\sigma_1}{d\tilde{p}} > 0$$

$$X_2 = \frac{2a_{131}}{\sigma_1} (R_v - 1) \, L^\eta + \frac{2a_{133} \, R_v}{\sigma_1} L^{2-\eta} < 0 \quad \text{if } R_v < 0$$

$$X_3 = - \frac{a_{131} \, R_v}{\sigma_0} L^\eta + \frac{2a_{133}}{\sigma_0} (1 - R_v) \, L^{2-\eta} < 0 \quad \text{if } R_v > 0$$

$$X_4 = Z_1 \, L^\eta + R_v \, L \frac{dm_1}{d\bar{p}} + \frac{2a_{133}}{\sigma_1} R_v \, L^{2-\eta} \frac{d\sigma_1}{d\bar{p}} > 0$$

$$X_5 = Z_2 \, L^\eta + Z_3 \, L + Z_4 \, L^{2-\eta} > 0$$

$$X_6 = Z_6 \, L^\sigma + Z_7 \, L^{2-\eta} < 0$$

b/ Blanks represent zeroes.

c/ Negative if $\rho < \sigma_0/\sigma_1$ or, equivalently, $R_v > 0$.

d/ Positive if $\rho < \sigma_0/\sigma_1$.

TABLE 4

$\frac{\partial x}{\partial y}$	x			
	$\hat{L}_{11}$	$\hat{L}_{12}$	$\hat{L}_{21}$	$\hat{L}_{22}$
m_1	$-\frac{L}{C} < 0$ a/	$\frac{\hat{L}_{12}}{(1+\eta)\,E(\Delta\pi)} > 0$		
σ_1	$\frac{BL^{2-\eta}\,\sigma_1}{C} > 0$	$-\frac{\hat{L}_{12}}{\sigma_1\,(1+\eta)}\left(1+\frac{\sigma_1}{\sigma_1-\rho\sigma_0}\right) < 0$		
w	$\frac{(1+r)L}{C} > 0$	$-\frac{(1+r)\,\hat{L}_{12}}{(1+\eta)\,E(\Delta\pi)} < 0$		$\frac{k}{(a-w)^2} > 0$
a			$-\frac{k}{a^2}$	$-\frac{k}{(a-w)^2}$
k	$\frac{r}{C} > 0$		$\frac{1}{a} > 0$	$\frac{1}{a-w} > 0$
y r	$\frac{k+wL}{C} > 0$	$-\frac{w\hat{L}_{12}}{(1+\eta)\,E(\Delta\pi)} < 0$		
m_0	$\frac{L}{C} > 0$	$-\frac{\hat{L}_{12}}{(1+\eta)\,E(\Delta\pi)} < 0$		
σ_0	$-\frac{BL^{2-\eta}\,\sigma_0}{C} < 0$	$\frac{\rho L_{12}}{(1+\eta)\,(\sigma_1-\rho\sigma_0)} > 0$		
$\bar{p}$	$-L\,\frac{dm_1}{d\bar{p}} + \frac{BL^{2-\eta}\,\sigma_1}{C}\,\frac{d\sigma_1}{d\bar{p}} < 0$	$\frac{\hat{L}_{12}}{1+\eta}\left[\frac{1}{E(\Delta\pi)}\,\frac{dm_1}{d\bar{p}} - \left(\frac{1}{\sigma_1}+\frac{1}{\sigma_1-\rho\sigma_0}\right)\frac{d\sigma_1}{d\bar{p}}\right] > 0$		
$\tilde{p}$	$\frac{-(1-B_m)\,L}{C}\,\frac{dm_1}{d\tilde{p}} + \frac{BL^{2-\eta}\,(\sigma_1-\beta_\sigma\,\sigma_0)}{C}\,\frac{d\sigma_1}{d\tilde{p}} < 0$	$\frac{\hat{L}_{12}}{1+\eta}\left[\frac{1-\beta_m}{E(\Delta\pi)}\,\frac{dm_1}{d\tilde{p}} - \left(\frac{1}{\sigma_1}+\frac{1-\rho\beta_\sigma}{\sigma_1-\rho\sigma_0}\right)\frac{d\sigma_1}{d\tilde{p}}\right] > 0$		
$\tilde{\sigma}$	$\frac{BL^{2-\eta}\,(\sigma_1-\beta_\sigma\,\sigma_0)\,\frac{d\sigma_1}{d\tilde{\sigma}}}{C} > 0$	$-\frac{L_{12}}{1+\eta}\left[\frac{1}{\sigma_1}+\frac{1-\rho\beta_\sigma}{\sigma_1-\rho\sigma_0}\right]\frac{d\sigma_1}{d\tilde{\rho}} > 0$		

a/ Note that $C = E(\Delta\pi) - (2-\eta)/2\;(\sigma_1^2 - \sigma_0^2)\;\beta L^{1-\eta} > 0$.

TABLE 5[a/]

$\frac{\partial E(\bar{U}_i)}{\partial y}$	y										
	m_1	σ_1	w	a	k	r_0	m_0	σ_0	$\bar{p}$	$\tilde{p}$	$\tilde{s}$
$\bar{U}_1$	+	-	-	0	-	-	+	-	+	+	-
$\bar{U}_2$	+	0	-	+	-	-	+	0	+	+	0

a/ Note that "+" implies nonnegativity and "-" implies nonpositivity.

$$\frac{\partial E(\bar{U}_i)}{\partial y} = \sum_{j=1}^{3} \int_{\hat{L}_{i,j-1}}^{\hat{L}_{i,j}} \frac{\partial \bar{U}_i(h)}{\partial y} \bar{F(L)}\, dL + \bar{U}_i\,(\hat{L}_{i,j})\, f(\hat{L}_{i,j})\, \frac{\partial \hat{L}_{i,j}}{\partial y}$$

$$- \bar{U}_i(\hat{L}_{i,j-1})\, f(\hat{L}_{i,j-1})\, \frac{\partial L_{i,j-1}}{\partial y} = \sum_{j=1}^{3} \int_{\hat{L}_{i,j-1}}^{\hat{L}_{ij}} \frac{\partial \bar{U}_i(L)}{\partial y} f(L)\, dL \qquad \text{(B7)}$$

since $\partial\hat{L}_{i0}/\partial y = \partial\hat{L}_{i3}/\partial y = 0$. Thus, since the signs in Table 3 are not contradictory between columns (except for σ_1 and σ_0), the results in Table 5 follow immediately. Table 6 further investigates the marginal distributional effects of policies by examining how the effects of policies on expected utility varies with farm size within each behavioral group.

Finally, the effects of policies on expected income distribution can be examined using (16) and (17) along with the results in Appendix A to obtain the results in Table 7. The results for the case of credit barriers to adoption are not shown in Table 7 since the results for $\partial Y_{ij}(L)/\partial y$ are identical to $\partial U_{ij}(L)/\partial y$ in Table 3. Finally, the results in Table 8 follow from an integration similar to (B7).

TABLE 6

	$\frac{\partial \bar{U}_{ij}(L)}{\partial L \partial y}$	$\bar{U}_{11}$	$\bar{U}_{12}$	$\bar{U}_{13}$	$\bar{U}_{21}$	$\bar{U}_{22}$	$\bar{U}_{23}$
	m_1	a/	1	$\frac{dL_1^*}{dL} < 1$		$\frac{a}{w} > 1$	1
	σ_1		$-(2 - \eta)B\sigma_1 L^{1-\eta} < 0$	y_1 b/			
	w		$-(1 + r) < -1$	$-(1 + r)\frac{dL_1^*}{dL}$		$-\frac{a}{w}\left[1 + r + \frac{E(\Delta\pi)}{w}\right] < -1$	$-(1 + r) < -1$
	a					$\frac{E(\Delta\pi)}{w}$	
	k		$-r\eta L^{\eta-1} < 0$				
y	r		$-k\eta L^{\eta-1} - w < 0$	$-w\frac{dL_1^*}{dL}$		$-a < 0$	$-w < 0$
	m_0	1		$1 - \frac{dL_1^*}{dL} \geq 0$	1	$1 - \frac{a}{w} < 0$	
	σ_0	$-(2 - \eta)B\sigma_0 L^{1-\eta}$		y_2 b/			
	$\bar{p}$		$\frac{dm_1}{d\bar{p}} - (2 - \eta)B\sigma_1 L^{1-\eta}\frac{d\sigma_1}{d\bar{p}} > 0$	y_3 c/		$a\frac{dm_1}{d\bar{p}} > 0$	$\frac{dm_1}{d\bar{p}} > 0$
	$\tilde{p}$	$y_4 > 0$	$\frac{dm_1}{d\tilde{p}} - (2 - \eta)B\sigma_1 L^{1-\eta}\frac{d\sigma_1}{d\tilde{p}} > 0$	y_5 c/	$\beta_m\frac{dm_1}{d\tilde{p}} > 0$	$\left[a(1 - \beta_m) + \beta_m\right]\frac{dm_1}{d\tilde{p}} > 0$	$\frac{dm_1}{d\tilde{p}} > 0$
	σ	$-(2 - \eta)B\sigma_0\beta_\sigma L^{1-\eta}\frac{d\sigma_1}{d\tilde{\sigma}} > 0$	$-(2 - \eta)B\sigma_1 L^{1-\eta}\frac{d\sigma_1}{d\tilde{\sigma}} > 0$	y_6 b/			

(Continued on next page.)

TABLE 6 continued.

a/ Blanks indicate zero.

b/ Negative if $\rho < \sigma_0/\sigma_1$ or, equivalently, $R_v > 0$.

c/ Positive if $\rho < \sigma_0/\sigma_1$.

$$y_1 = \frac{2\eta\, a_{131}}{\sigma_1} (R_v - 1)\, L^{\eta-1} + \frac{2a_{133}\,(2-\eta)\, R_v}{\sigma_1} L^{1-\eta} < 0 \text{ if } R_v > 0$$

$$y_2 = -\frac{\eta a_{131}\, R_v}{\sigma_0} L^{\sigma-1} + \frac{2a_{133}\,(2-\eta)}{\sigma_0} (1 - R_v)\, L^{1-\eta} < 0 \text{ if } R_v > 0$$

$$y_3 = \eta Z_1\, L^{\eta-1} + R_v \frac{dm_1}{d\bar{p}} + \frac{2a_{133}\,(2-\eta)}{\sigma_1} R_v\, L^{1-h} \frac{d\sigma_1}{dp} > 0 \text{ if } R_v \gtrless 0$$

$$y_4 = \beta_m \frac{dm_1}{d\bar{p}} - (2-\eta) B\, \sigma_0\, \beta_\sigma\, L^{1-\eta} \frac{d\sigma_1}{d\bar{p}} > 0$$

$$y_5 = \eta Z_2\, L^{\eta-1} + Z_3 + (2-\eta)\, Z_4\, L^{1-\eta} > 0 \text{ if } R_v > 0$$

$$y_6 = \eta Z_6\, L^{\eta-1} + (2-\eta)\, Z_7\, L^{1-\eta} < 0 \text{ if } R_v > 0$$

TABLE 7

$\frac{M_i y_j\ (L)}{My}$		y_{11}	y_{12}	y_{13}
	m_1	a/	$L > 0$	$L_1^* + E(\Delta\pi)\frac{dL_1^*}{dm_1} > 0$
	σ_1			$E(\Delta\pi)\frac{dL_1^*}{d\sigma_1} < 0$
	w		$-(1+r)L < 0$	$-(1+r)L_1^* + E(\Delta\pi)\frac{dL_1^*}{dw} < 0$
	a			
	k		$-r < 0$	$-r < 0$
y	r		$-k < 0$	$-k + E(\Delta\pi)\frac{dL_1^*}{dr} < 0$
	m_0	$L > 0$		$L - L_1^* + E(\Delta\pi)\frac{dL_1^*}{dm_0} > 0$ b/
	σ_0			$E(\Delta\pi)\frac{dL_1^*}{d\sigma_0}$ c/
	$\bar{p}$		$L\frac{dm_1}{d\bar{p}} > 0$	$L_1^*\frac{dm_1}{d\bar{p}} + E(\Delta\pi)\frac{dL_1^*}{d\bar{p}} > 0$
	$\tilde{p}$	$\beta_m L\frac{dm_1}{d\tilde{p}} > 0$	$L\frac{dm_1}{d\tilde{p}} > 0$	$L_1^*\frac{dm_1}{d\tilde{p}} + \beta_m(L - L_1^*)\frac{dm_1}{d\tilde{p}} + E(\Delta\pi)\frac{dL_1^*}{d\tilde{p}}$
	$\tilde{\sigma}$			$E(\Delta\pi)\frac{dL_1^*}{d\tilde{\sigma}}$ d/

a/ Blanks indicate zero.

b/ Note that using (A11) with constant absolute risk aversion obtains $dL_1^*/dm_0 = -[\phi V(\Delta\pi)]^{-1}$.

c/ Negative in the high correlation case with $\rho > 2\sigma_0/\sigma_1$ and positive in the low correlation case with $\rho < 2\sigma_0/\sigma_1$.

d/ Negative in the high correlation case with $\rho > \beta_\sigma$ and positive in the low correlation case with $\rho < \beta_\sigma$.

TABLE 8

$\frac{\partial E(y_i)}{\partial y}$	m_1	σ_1	w	a	k	r	m_0	σ_0	$\bar{p}$	$\tilde{p}$	$\tilde{\sigma}$
$E(y_1)$	+	-	-	0	-	-	+	?a/	+	?b/	?c/
$E(y_2)$	+	0	-	+	-	-	+	0	+	+	0

a/ Negative in the high correlation case with $\rho > 2\ \sigma_0/\sigma_1$ and positive in the low correlation case with $\rho < 2\ \sigma_0/\sigma_1$.

b/ Positive if correlation is high ($\rho > \beta_\sigma$) and the expected per hectare gains from adoption are high ($\beta_m < L_1/L_0$) among partial adopters.

c/ Negative in the high correlation case with $\rho > \beta_\sigma$ and positive in the low correlation case with $\rho < \beta_\sigma$.

Footnotes

The authors are professor, professor and chairman, and assistant professor of agricultural and resource economics, University of California, Berkeley, respectively. This work has been done as part of BARD project 1-10-79.

[1]In addition, the mathematical derivation requires $\beta_\sigma \leq \beta_m$ which is consistent with the assumption that the new technology is viewed as relatively more risky by the farmer.

[2]The complete equity implications for the six classes of farms identified here, as well as other classes, will be drawn out in a future manuscript. The analysis will be based on the results that appear in Table 6 of Appendix B.

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