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by

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1. Introduction

The agricultural industry is often cited as a classic example of a competitive market. The observed performance of such markets, however, is the result not only of competitive forces but also of governmental intervention. Such intervention is often motivated by equity or distributional concerns. Typically, the impact of such governmental intervention is evaluated only in terms of output markets (Brandow). Such investigations are grossly inadequate since governmental policies impinge directly on asset as well as flow markets for both inputs and outputs. In general, the distributional consequences depend upon the ownership, utilization, quality, and technology associated with the assets.

This paper develops a framework for capturing the distributional implications of governmental intervention in the agricultural sector recognizing its most important features. These features include (i) competitiveness, (ii) asset fixity, (iii) rapid technological change, and (iv) institutional limits to credit availability. The first three features are documented by Theodore Schultz, Willard Cochrane, and G. L. Johnson. Theodore Schultz has also called attention to the large differences in the rates of return to resources among regions as well as across producers. Much of this variation emanates from differences in production techniques, human capital, and wealth controlled by individual producers. The limitations of credit availability for producers of different size classes have been noted by recent empirical evidence. This evidence strongly suggests that larger farmers borrow more; they borrow more to invest in capital; and their ability to borrow more stems, in part, from their higher repayment capacity (Baker; Quinn; Riboud).

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. For example, in the agricultural development literature, 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. Also, the distributional content of results forthcoming from such models is not very rich.

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 the aggregate level. Assuming the major source of economic growth is technological change, the framework focuses 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.

To accomplish these purposes, a stylized model involving two technologies, traditional and new, is specified. At both the microlevel 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 price support, credit-funding enhancement, credit subsidies, crop insurance, price stabilization, input subsidies, and extension promotion.

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 examines the operational use of the framework.

2. The Micromodel

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 acre $\pi_0 = p_0 y_0$ 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 "new crop," may be a new high-yielding variety or a cash crop utilizing a new input such as fertilizer, insecticide, or drip irrigation. 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 acre. Additional (and subjective) uncertainty may also accompany the new crop because the farmer is less familiar with the new technology. Considering this factor, the new crop may be viewed as more risky even if, in reality, it is not more susceptible to extreme weather situations than is the traditional crop.

Suppose production of the new crop requires a cost of w for the new input per acre. Suppose the (opportunity) cost of funds used to finance the new 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 new crop, respectively. Also, suppose that net returns of the traditional and new crops are jointly normally distributed with

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

with the relevant covariance matrix assumed to be positive definite; further reasonable assumptions include $m_0 > 0$, $m_1 > 0$, $m_0 = \beta_m m_1 < m_1$, $\sigma_0 = \beta_\sigma \sigma_1 < \sigma_1$, $\rho \geq 0$. Thus, the new crop is more profitable in expectations but also more risky. 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 setup 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 setup cost, k , for which the annualized cost is rk , the farmer also incurs a variable cost, w per acre, 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 new technology is not adopted, $I = 1$ if the new 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 $U(\cdot)$ defined on wealth, $U' > 0$, $U'' \leq 0$. 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

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

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 are not 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

$$U_0(L) = EU[(p_L + \pi_0) L]. \quad (2)$$

Alternatively, given adoption and assuming full land utilization, the objective of the decision problem in (1) becomes

$$\max_{L \geq L_1 \geq 0} EU[(p_L + \pi_0) L + (\pi_1 - \pi_0) L_1 - rk] \quad (3)$$

subject to

$$k + wL_1 \leq K.$$

LEMMA 1. The solution to (3) subject to the constraints is approximated by

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

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

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

$$R = \frac{\sigma_0^2 - \rho\sigma_0\sigma_1}{V(\Delta\pi)} \quad (6)$$

$$\Delta\pi = \pi_1 - \pi_0 \quad (7)$$

$$\phi = \frac{-U''(\bar{W})}{U'(\bar{W})} \quad (8)$$

$$\bar{W} = p_L L + m_0 L + E(\Delta\pi) L_1 - rk, \quad (9)$$

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

Proof. Just, Zilberman, and Raussier show that the objective function in (3) is strictly concave in L_1 . Thus, either the optimum must be attained internally and be equivalent to the unconstrained optimum or the optimum must be attained at one of the points at which constraints are binding. The first-order condition for maximization of the unconstrained problem is

$$\frac{dEU}{dL_1} = E[U'(\Delta\pi)] = 0$$

where $\Delta\pi = \pi_1 - \pi_0$; and, as shown by Just and Zilberman, is approximated by

$$E(\Delta\pi) - \phi[L_1 V(\Delta\pi) + L(\rho\sigma_0 \sigma_1 - \sigma_0^2)] = 0. \quad (10)$$

The solution, L_1^* , is given by (5) using (6) through (9). Thus, based on the strict concavity of (3) in L_1 , the solution to the constrained problem is given by (4). From (10), the second-order condition is

$$- \phi V(\Delta\pi) \left[1 + \frac{\phi' E^2(\Delta\pi)}{\phi^2 V(\Delta\pi)} \right] < 0.$$

Just and Zilberman show that

$$D \equiv 1 + \frac{\phi' E^2(\Delta\pi)}{\phi^2 V(\Delta\pi)} \geq 0, \quad (11)$$

assuming perceived average income is less than expected wealth at the end of the production period (which includes perceived income). Thus, second-order conditions hold under risk aversion.

REMARK 1. The result in Lemma 1 is clear intuitively 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. Note that the broken lines in Figure 1 correspond to the solution L_1^* where negative choices for land quantities are possible. Thus, by concavity of the objective function, the optimum is at point c if $L_1^* < 0$. If

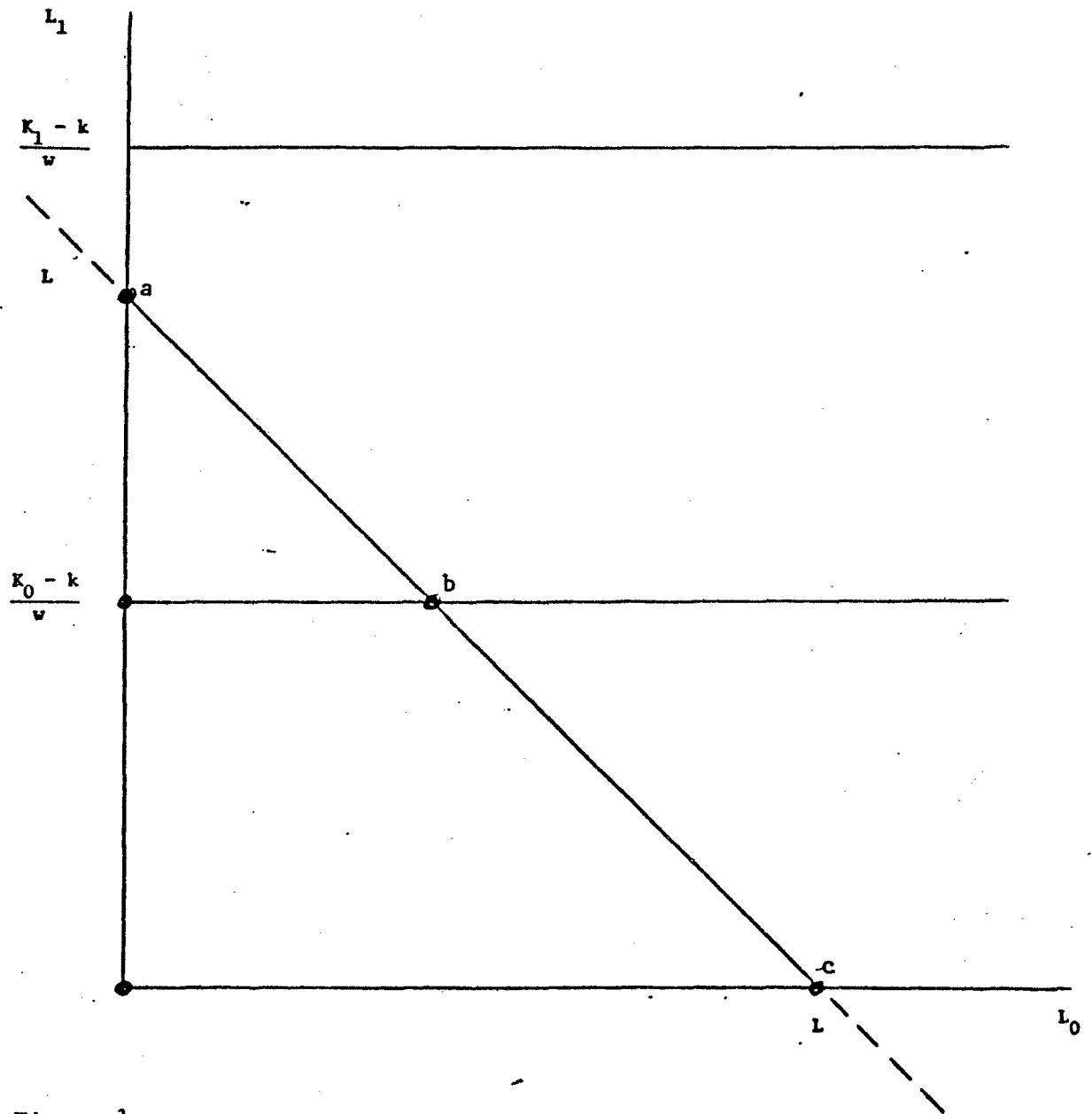


Figure 1

credit is abundant (e.g., $K = K_1$ in Figure 1), 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, 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

$$U_1(L, L_1^-) = EU[p_L L + \pi_0(L - L_1^-) + \pi_1 L_1^- - rk].$$

Assuming either that the farmer is myopic (or considers future periods will 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, this section investigates the mathematical properties of farmer behavior under several alternative 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 policies considered are price support, crop insurance, price stabilization, and extension promotion. 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 , m_0 , and σ_0 . Specifically, a price support is assumed to cause the expected returns per acre under the new technology, m_1 , to increase, and the

variability of returns per acre under the new technology, σ_1 , to decrease. Denoting such a price-support level by $\bar{p}$, the effect of a change in the price must be represented as an effect of $\bar{p}$ through both m_1 and σ_1 ($dm_1/d\bar{p} > 0$, $d\sigma_1/d\bar{p} < 0$). If the price support also applies to the existing crop, similar effects are assumed for the old technology. Denoting this type of price support by $\tilde{p}$, the effect of a price-support change must be reflected through m_0 , σ_0 , m_1 , and σ_1 ($dm_i/d\tilde{p} > 0$, $d\sigma_i/d\tilde{p} < 0$, $i = 1, 2$). The assumption for this case is that the effect on both expected returns and variability of returns per acre under the old technology is relatively less ($m_0 = \beta_m m_1$ where $0 < \beta_m < 1$ and $\sigma_0 = \beta_\sigma \sigma_1$ where $0 < \beta_\sigma < 1$).

Crop insurance is assumed to be actuarially fair and lower the variability of returns per acre under the new technology, σ_1 , without affecting expected returns per acre. 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 acre under the old technology is relatively less (as suggested by the assumption that the new technology is viewed as relatively more risky). Denoting the level of insurance by $\tilde{\sigma}$, a change in the level of insurance is represented through a change in both σ_0 and σ_1 ($d\sigma_i/d\tilde{\sigma} > 0$, $i = 1, 2$). The effect of price stabilization is thus the same as for crop insurance.

Two types of extension effects are considered. Extension contacts can cause a farmer to increase his subjective expectations of returns per acre under the new technology, m_1 , and/or to reduce his subjective variability of returns under the new technology, σ_1 .

LEMMA 2. Suppose a farmer adopts a new technology that is viewed as relatively more risky than the old technology and that absolute risk aversion

is nonincreasing ($\phi' \leq 0$). Then the effects of policy instruments on land allocation satisfy

$$\frac{dL_1}{dm_1} = \begin{cases} \frac{1}{\phi DV(\Delta\pi)} \left[1 - \frac{\phi' L_1 E(\Delta\pi)}{\phi} \right] > 0 & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \quad (12)$$

$$\frac{dL_1}{d\sigma_1} = \begin{cases} -\frac{1}{DV(\Delta\pi)} [L_1(2\sigma_2 - \rho\sigma_0) + L_0\rho\sigma_0] < 0 & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \quad (13)$$

$$\frac{dL_1}{dm_0} = \begin{cases} -\frac{1}{\phi DV(\Delta\pi)} \left[1 - \frac{\phi'(L - L_1) E(\Delta\pi)}{\phi} \right] < 0 & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \quad (14)$$

$$\frac{dL_1}{d\sigma_0} = \begin{cases} \frac{2\sigma_0 - \rho\sigma_1}{DV(\Delta\pi)} (L - L_1) \geq 0 \text{ as } p \leq 2 \frac{\sigma_0}{s_1} & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \quad (15)$$

$$\frac{dL_1}{dp} = \begin{cases} \frac{dL_1}{dm_1} \frac{dm_1}{dp} + \frac{dL_1}{d\sigma_1} \frac{d\sigma_1}{dp} \geq 0 & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \quad (16)$$

$$\frac{dL_1}{dp} = \begin{cases} \left[\frac{dL_1}{dm_1} + \frac{dL_1}{dm_0} \beta_m \right] \frac{dm_1}{dp} + \left[\frac{dL_1}{d\sigma_1} + \frac{dL_1}{d\sigma_0} \beta_\sigma \right] \frac{d\sigma_1}{dp} & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \quad (17)$$

$$\frac{dL_1}{d\sigma} = \begin{cases} \left[\frac{dL_1}{d\sigma_1} + \frac{dL_1}{d\sigma_0} \beta_\sigma \right] \frac{d\sigma_1}{d\sigma} \gtrless 0 \text{ as } \rho \gtrless \beta_\sigma & \text{if IS} \\ 0 & \text{if LB, BC, or UB} \end{cases} \quad (18)$$

were LB denotes a lower bound solution, $L_1^* < 0$ or $k > K$; IS denotes the case of an internal solution, $0 \leq L_1^* \leq L$ and $(K - k)/w > 0$; BC denotes the case of a binding credit solution, $L \geq L_1^* > (K - k)/w > 0$; and UB denotes the case of a upper bound solution, $(K - k)/w > L$ and $L_1^* > L$.

Proof. Immediate from (4) and (11).

REMARK 2. Note that definite results are obtained in all cases except (17) where, in the case of IS,

$$\begin{aligned} \frac{dL_1}{d\tilde{p}} &= \frac{1}{\phi DV(\Delta\pi)} \left[1 - \beta_m - \frac{\phi' E(\Delta\pi)}{\phi} (L_1 - \beta_m L_0) \right] \frac{d\tilde{m}_1}{d\tilde{p}_0} \\ &\quad - \frac{1}{DV(\Delta\pi)} \left[(2\sigma_1 - \rho\sigma_0) L_1 + \rho\sigma_0 L - \beta_s (2\sigma_0 - \rho\sigma_1) L_0 \right] \frac{d\sigma_1}{d\tilde{p}_0}. \end{aligned}$$

The second component in brackets in the second term has the same sign as $\rho - \beta_\sigma$ obtained in (18). 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 $\beta_m \beta L_1/L_0$. Furthermore, if β_m is close to one, the expected gain from adoption is small while variability increases with adoption so L_1/L_0 tends to be low, i.e.,

$$\lim_{\beta_m \rightarrow 1} \frac{L_1}{L_0} = 0.$$

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 $\beta_m \rightarrow 1$.

4. The Macromodel

To examine policy issues quantitatively in the context of the 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 considering a distribution of farm size, $f(L)$, and then specifying a relationship between farm size and risk preferences and credit.

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

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

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

$$K = aL.$$

This relationship is consistent with many general credit-granting practices. Finally, note that, following the assumption of constant absolute risk aversion for individual farmers, one can write

$$U_0(L) = (p_L + m_0) L - \frac{\phi}{2} \sigma_0^2 L^2 \quad (19)$$

$$\begin{aligned}
 U_1(L, L_1) = & (p_L + m_0) L + (m_1 - m_0) L_1 - rk \\
 & - \frac{\phi}{2} [\sigma_0^2 (L - L_1)^2 + \sigma_1^2 L_1^2 + 2\rho \sigma_0 \sigma_1 L_1 (L - L_1)].
 \end{aligned}
 \tag{20}$$

Using the model of section 3, the relationship of adoption intensity and farm size can be determined as illustrated in Figures 2 and 3 following (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 spread adequately to make adoption worthwhile.

Note that Figure 2 is drawn to depict the case where the major barriers to adoption are risk aversion and setup costs. Below farm size $\hat{L}_{11}$, fixed costs cannot be spread adequately to justify adoption. At farm size $\hat{L}_{12}$, 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 3 is drawn to depict the case where the major barriers to adoption are credit and setup costs and farmers are risk neutral. Below farm size $\hat{L}_{21}$, fixed costs cannot be spread adequately 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 2 and 3 exist. For example, Figure 3 is drawn to depict the case of risk neutrality where $L_1 = L_1^*$ becomes vertical at $L = 0$. If risk aversion is

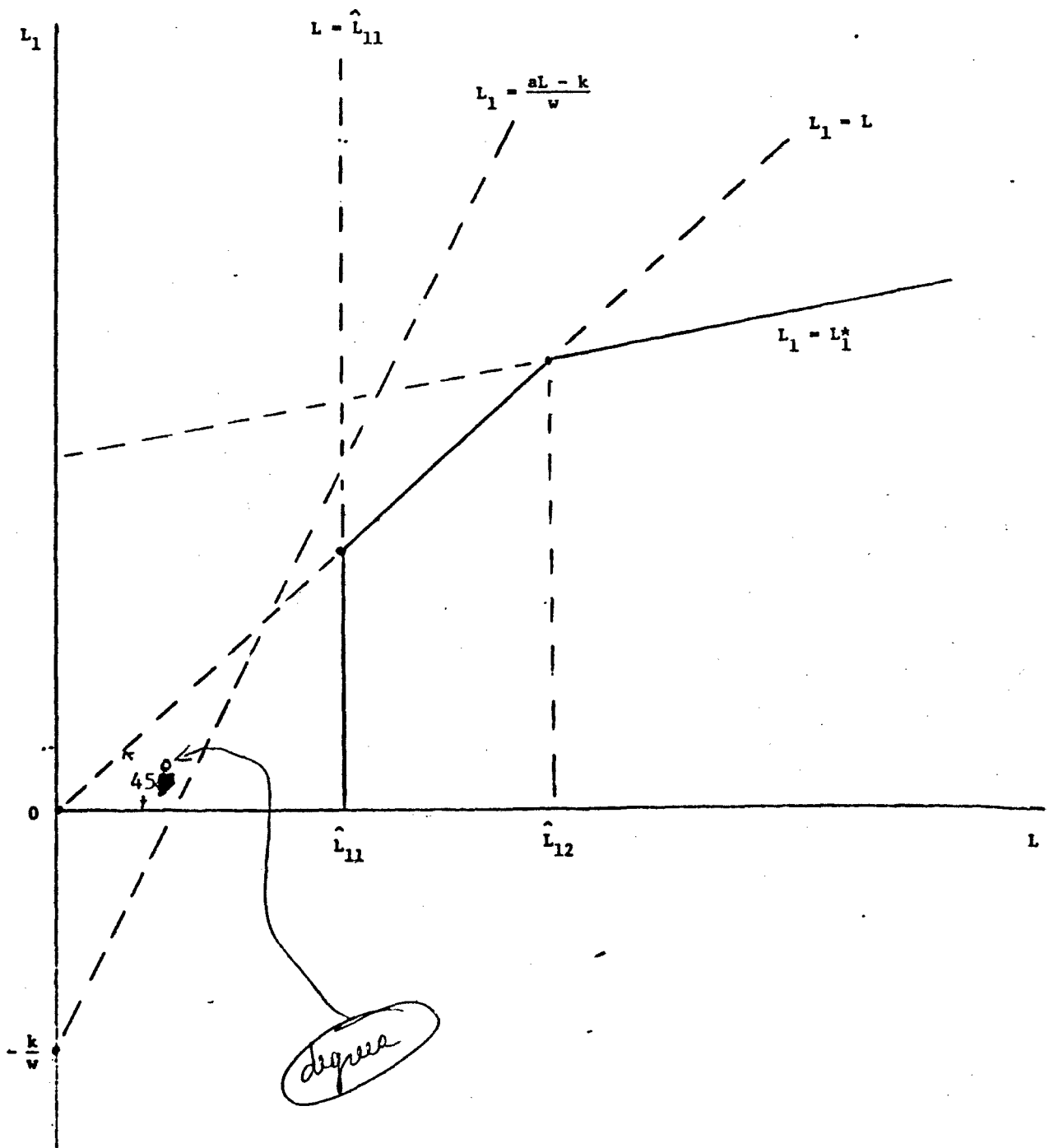


Figure 32

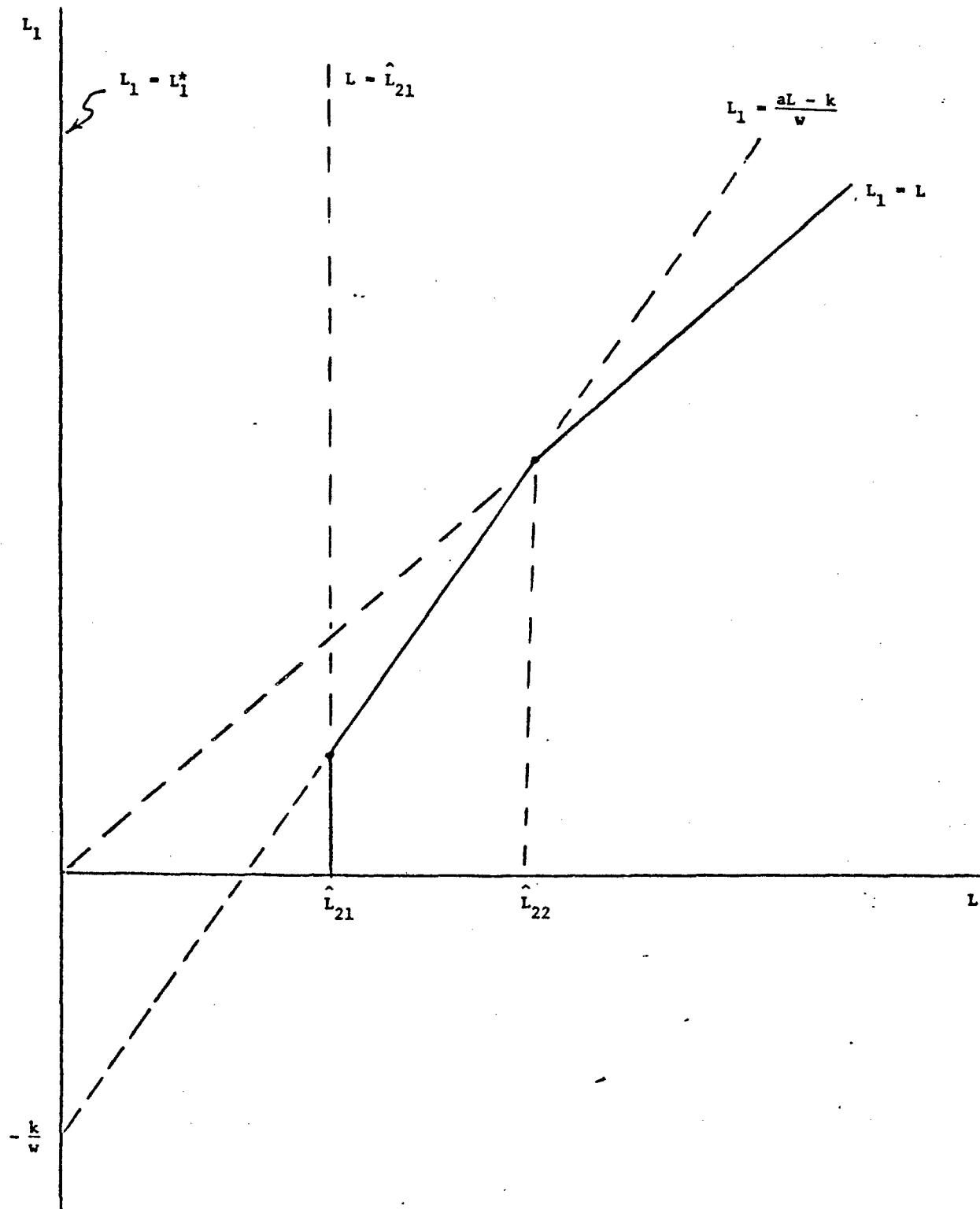


Figure 43

introduced in Figure 3, then $L_1 = L_1^*$ rotates downward and intersects $L_1 = L$ as in Figure 2. 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 acre, 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 the 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.¹ Casual observation suggests that many adoption problems involve at least some farmers who fully adopt and some farmers who only partially adopt because of either excessive perceived risk with the new technology or credit limitations. The two cases below focus 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 2. In the second

case, any partial adoption is assumed to be due to insufficient credit as in Figure 3. For ease of exposition, this case is considered only 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, $\hat{L}_0 = \hat{L}_{i0} < \hat{L}_{i1}$ is assumed.

5. Efficiency Effects of Agricultural Policies

Efficiency will be examined by investigating the effects of various policies on the mean of the expected utility in (23) and (20). Note that, under the assumptions of this section, the quantities in (19) and (20) are certainty equivalents, are 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:

$$E(\bar{U}_i) = \int_{\hat{L}_{i0}}^{\hat{L}_{i3}} \bar{U}_i(L) f(L) dL \quad (21)$$

where

$$\bar{U}_1(L) = \begin{cases} U_0(L) & \text{if } \hat{L}_{10} \leq L < \hat{L}_{11} \\ U_1(L, L) & \text{if } \hat{L}_{11} \leq L \leq \hat{L}_{12} \\ U_1(L, L_1^*) & \text{if } \hat{L}_{12} \leq L < \hat{L}_{13} \end{cases} \quad (22)$$

when the major barriers to adoption are risk aversion, setup costs, and

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

when the major barriers to adoption are credit and setup costs.

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

$$E(Y_i) = \int_{\hat{L}_{i0}}^{\hat{L}_{i3}} Y_i(L) f(L) dL, \quad (24)$$

where

$$Y_1(L) = \begin{cases} m_0 L & \text{if } \hat{L}_{10} \leq L \leq \hat{L}_{11} \\ m_1 L - rk & \text{if } \hat{L}_{11} \leq L \leq \hat{L}_{12} \\ m_0 L + (m_1 - m_0) L_1^* - rk & \text{if } \hat{L}_{12} \leq L \leq \hat{L}_{13} \end{cases} \quad (25)$$

when the major barriers to adoption are risk aversion and setup costs and

$$Y_2(L) = \begin{cases} m_0 L & \text{if } \hat{L}_{20} \leq L \leq \hat{L}_{21} \\ m_0 L + E(\Delta\pi) \frac{aL - k}{w} - rk & \text{if } \hat{L}_{21} \leq L \leq \hat{L}_{22} \\ m_0 L + E(\Delta\pi) L_1^* - rk & \text{if } \hat{L}_{22} \leq L \leq \hat{L}_{23} \end{cases} \quad (26)$$

when the major barriers to adoption are credit and setup costs.

The popular measure (24) is obviously a misspecification of the welfare measure (21); the magnitude of bias in using (24) in lieu of (21) depends upon the degree of risk aversion. In any event, since (24) is frequently employed in empirical analysis, the propositions derived in this section focus on these performance measures as well as (21). 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 by solving for L_{11} and L_{12} , performing the integration in (21) and (24), 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 introduced easily, but the exposition and understanding of propositions becomes less clear when such effects are introduced. Furthermore, the modifications introduced by such considerations follow intuition.

First, note from (4) and (22), where $\phi = BL^{-\eta}$, that

$$L_{12} = \left[\frac{E(\Delta\pi)}{B(\sigma_1^2 - \rho\sigma_1\sigma_0)} \right]^{\frac{1}{1-\eta}} \quad (27)$$

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

$$E(\Delta\pi) \hat{L}_{11} - \frac{1}{2} \hat{B} L_{11}^{2-\eta} (\sigma_1^2 - \sigma_0^2) - rk = 0. \quad (28)$$

for the case where the major barriers to adoption are risk aversion and setup costs [$U_0(\hat{L}_{11}) = U_1(\hat{L}_{11}, \hat{L}_{12})$ and $U_1(\hat{L}_{11}, \hat{L}_{11}) = U_1(\hat{L}_{11}, L_1^*)$] and from (4) and (27) that

$$\hat{L}_{21} = \frac{k}{a} \quad (29)$$

$$\hat{L}_{22} = \frac{k}{a - w} \quad (30)$$

under risk neutrality ($\phi = 0$) for the case where the major barriers to adoption are credit and setup 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,

$$E(\bar{U}_i) = \sum_{j=1}^3 \int_{\hat{L}_{i,j-1}}^{\hat{L}_{i,j}} U_i(L) f(L) dL \quad (31)$$

where

$$\bar{U}_i(L) = \bar{U}_{ij}(L) \equiv a_{ij0} + a_{ij1}L^\eta + a_{ij2}L + a_{ij3}L^{2-\eta} \text{ for } L \in \mathcal{L}_{ij} \equiv (\hat{L}_{i,j-1}, \hat{L}_{i,j}) \quad (32)$$

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 farms using equation (32) and Table 2, i.e.,

$$\frac{\partial \bar{U}_{ij}(L)}{\partial y} = \frac{\partial a_{ij0}}{\partial y} + \frac{\partial a_{ij1}}{\partial y} L^\eta + \frac{\partial a_{ij2}}{\partial y} L + \frac{\partial a_{ij3}}{\partial y} L^{2-\eta}$$

where $y = m_1, \sigma_1, \dots, \tilde{\sigma}$. Note that some of these result are derived by duality and the asterisk on L_0 and L_1 is dropped for simplicity. 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 (27) through (30). Table 5 investigates the marginal efficiency effects of various policies by differentiating the overall expected utility in (31) using Table 3 and Liebniz' rule, i.e.,

$$\begin{aligned} \frac{\partial E(\bar{U}_i)}{\partial y} &= \sum_{j=1}^3 \int_{\hat{L}_{i,j-1}}^{\hat{L}_{i,j}} \frac{\partial \bar{U}_i(h)}{\partial y} f(L) dL + \bar{U}_i(\hat{L}_{i,j}) f(\hat{L}_{i,j}) \frac{\partial \hat{L}_{i,j}}{\partial y} \\ &\quad - \bar{U}_i(\hat{L}_{i,j-1}) f(\hat{L}_{i,j-1}) \frac{\partial \hat{L}_{i,j-1}}{\partial y} = \sum_{j=1}^3 \int_{\hat{L}_{i,j-1}}^{\hat{L}_{i,j}} \frac{\partial \bar{U}_i(L)}{\partial y} f(L) dL \end{aligned} \quad (33)$$

TABLE 1
Coefficients of Expected Utility

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

^{a/} Note that $\sigma_0^2 - R^2 V(\Delta\pi) = \sigma_0^2 \sigma_1^2 (1 - \rho^2)/V(\Delta\pi)$.

TABLE 2

Policy Effects on Coefficients of Expected Utility

X	Y						
	m_1	σ_1	m_0	σ_0	$\bar{p}$	p	σ
				ax/ay			
a_{112}	$a/$		1			$\beta_m \frac{dm_1}{dp}$	
a_{113}				$-B\sigma_0$		$-B\sigma_0 \beta_\sigma \frac{d\sigma_1}{dp}$	$-B\sigma_0 \beta_0 \frac{d\sigma_1}{d\sigma}$
a_{120}							
a_{122}	1				$\frac{dm_1}{d\bar{p}}$	$\frac{dm_1}{dp}$	
a_{123}		$-B\sigma_1$			$-B\sigma_1 \frac{d\sigma_1}{d\bar{p}}$	$-B\sigma_1 \frac{d\sigma_1}{dp}$	$-B\sigma_1 \frac{d\sigma_1}{d\sigma}$
a_{130}							
a_{131}	$\frac{2a_{131}}{E(\Delta\pi)}$	$\frac{2a_{131}}{\sigma_1} (R - 1)$	$-\frac{2a_{131}}{E(\Delta\pi)}$	$-\frac{2a_{131}R}{\sigma_0}$	z_1	z_2	z_6
a_{132}	R	$-\frac{E(\Delta\pi)}{V(\Delta\pi)} [\rho\sigma_0 + 2R(\sigma_1 - \rho\sigma_0)]$	$1 - R$	$-\frac{E(\Delta\pi)}{V(\Delta\pi)} [\rho\sigma_1 + 2R(\sigma_0 - \rho\sigma_1)]$	$R \frac{dm_1}{d\bar{p}}$	z_3	
a_{133}		$\frac{2a_{133} R}{\sigma_1}$		$2a_{133} \frac{1 - R}{\sigma_0}$	$\frac{2a_{133} R}{\sigma_1} \frac{d\sigma_1}{d\bar{p}}$	z_4	z_7
a_{212}			1			$\beta_m \frac{dm_1}{dp}$	
a_{220}	$-\frac{k}{w}$		$\frac{k}{w}$		$-\frac{k}{w} \frac{dm_1}{d\bar{p}}$	$\frac{k}{w} (\beta_m - 1) \frac{dm_1}{dp}$	
a_{222}	$\frac{a}{w}$		$1 - \frac{a}{w}$		$\frac{a}{w} \frac{dm_1}{d\bar{p}}$	z_5	
a_{230}							
a_{232}	1				$\frac{dm_1}{d\bar{p}}$	$\frac{dm_1}{dp}$	

(Continued on next page.)

TABLE 2--continued.

a/ Blanks indicate zero.

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

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

$$Z_3 = [R + \beta_m(1-R)] \frac{dm_1}{dp} > 0 \text{ if } R > -\frac{\beta_m}{1-\beta_m}$$

$$Z_4 = \frac{2a_{133}}{\sigma_0\sigma_1} [R\sigma_0 + (1-R)\beta_\sigma\sigma_1] \frac{d\sigma_1}{dp}$$

$$Z_5 = \left[\frac{a}{w} + \left(\beta_m 1 - \frac{a}{w} \right) \right] \frac{dm_1}{dp} > 0$$

$$Z_6 = \frac{2a_{131}}{\sigma_0\sigma_1} [(R-1)\sigma_0 - R\beta_\sigma\sigma_1] \frac{d\sigma_1}{ds} < 0$$

$$Z_7 = \frac{2a_{133}}{\sigma_0\sigma_1} [R\sigma_0 + (1-R)\beta_s\sigma_1] \frac{d\sigma_1}{d\delta} < 0$$

TABLE 3a/

Effects of Policies on Expected Utility by Farm Size/Case

y	Farm size/case					
	$\bar{U}_{11}$	$\bar{U}_{12}$	$\bar{U}_{13}$	$\bar{U}_{21}$	$\bar{U}_{22}$	$\bar{U}_{23}$
	----- $\partial \bar{U}_{ij} / \partial y$ -----					
m_1	$\underline{b}/$	$L > 0$	$L_1 > 0$		$L_1 > 0$	$L > 0$
σ_1		$-B\sigma_1 L^{2-\eta} < 0$	$X_2 < 0$			
m_0	$L > 0$		$-L_1 + L > 0$	$L > 0$	$L - L_1 > 0$	
σ_0	$-B\sigma_0 L^{2-\eta} < 0$		$X_3 < 0$			
$\bar{p}$		$L \frac{dm_1}{d\bar{p}} - B\sigma_1 L^{2-\eta} \frac{d\sigma_1}{d\bar{p}} > 0$	$X_4 > 0$		$L_1 \frac{dm_1}{d\bar{p}} > 0$	$L \frac{dm_1}{d\bar{p}} > 0$
$\tilde{p}$	$X_1 > 0$	$L \frac{dm_1}{d\tilde{p}} - B\sigma_1 L^{2-\eta} \frac{d\sigma_1}{d\tilde{p}} > 0$	$X_5 > 0$	$\beta_m L \frac{dm_1}{d\tilde{p}} > 0$	$[L_1(1 - \beta_m) + \beta_m L] \frac{dm_1}{d\tilde{p}} > 0$	$L \frac{dm_1}{d\tilde{p}} > 0$
$\tilde{\sigma}$	$-B\sigma_0 \beta_\sigma L^{2-\eta} \frac{d\sigma_1}{d\sigma} < 0$	$-B\sigma_1 L^{2-\eta} \frac{d\sigma_1}{d\sigma} < 0$	$X_6 < 0$			

(Continued on next page.)

TABLE 3--continued.

a/ Definitions of X_i are as follows:

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

$$X_2 = -\phi[\sigma_1 L_1^2 + \rho \sigma_0 L_0 L_1] < 0$$

$$X_3 = -\phi[\sigma_0 L_0^2 + \rho \sigma_1 L_0 L_1] < 0$$

$$X_4 = L_1 \frac{dm_1}{dp} - \phi[\sigma_1 L_1^2 + \rho \sigma_0 L_0 L_1] \frac{d\sigma_1}{dp} > 0$$

$$X_5 = z_2 L^\eta + z_3 L + z_4 L^{2-\eta} > 0$$

$$X_6 = z_6 L^\eta + z_7 L^{2-\eta} < 0$$

b/ Blanks represent zeroes.

TABLE 4

Effects of Policies on Critical Farm Scales

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

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

TABLE 5a/
Welfare Effects of Policies by Case

Case	γ						
	m_1	σ_1	m_0	σ_0	$\bar{p}$	p	σ
	----- $\partial EU_i / \partial \gamma$ -----						
$\bar{U}_1$	+	-	+	-	+	+	-
$\bar{U}_2$	+	0	+	0	+	+	0

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

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.

Finally, the effects of policies on expected income distribution can be examined using (25) and (26) along with the results in Lemma 2 to obtain the results in Table 6. The results for the case of credit barriers to adoption are not shown in Table 6 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 7 follow from an integration similar to (37). Tables 1 through 7 prove Propositions 1 through 5.

Proposition 1: Price Support for a New Crop. 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, and full adopters and partial adopters become better off. Where risk aversion and setup costs are the major barriers to adoption, the minimum scale required for adoption declines and the maximum size of fully adopting farms increases; thus, more adoption is induced. In the case where credit and setup costs are the major barriers to adoption, neither the critical levels of adoption nor overall adoption is affected.

Proposition 2: Price Support for an Existing Crop. 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 setup 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 setup costs. In this case, the well-being of every individual farmer is improved according to

TABLE 6

Effects of Policies on Expected Income by Farm Size

y	Farm size		
	y ₁₁	y ₁₂	y ₁₃
	----- $\partial x_{ij} / \partial y$ -----		
m ₁	a/	L > 0	$L^* + E(\Delta\pi) \frac{dL_1^*}{dm_1} > 0$
σ_1			$E(\Delta\pi) \frac{dL_1^*}{d\sigma_1} < 0$
m ₀		L > 0	$L - L_1^* + E(\Delta\pi) \frac{dL_1^*}{dm_0} > 0$ ^{b/}
σ_0			$E(\Delta\pi) \frac{dL_1^{*c/}}{d\sigma_0}$
$\bar{p}$		$L \frac{dm_1}{d\bar{p}} > 0$	$L_1^* \frac{dm_1}{d\bar{p}} + E(\Delta\pi) \frac{dL_1^*}{d\bar{p}} > 0$
$\tilde{p}$	$\beta_m L \frac{dm_1}{d\tilde{p}} > 0$	$L \frac{dm_1}{d\tilde{p}} > 0$	$L_1^* \frac{dm_1}{d\tilde{p}} + \beta_m (L - L_1^*) \frac{dm_1}{d\tilde{p}} + E(\Delta\pi) \frac{dL_1^*}{d\tilde{p}}$
$\tilde{\sigma}$			$E(\Delta\pi) \frac{dL_1^{*d/}}{d\tilde{\sigma}}$

^{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 7
Aggregate Income Effects of Policies by Case

Case	y						
	m_1	σ_1	m_0	σ_0	$\bar{p}$	$\tilde{p}$	σ
	$\partial E(Y_i)/\partial y$						
$E(Y_1)$	+	-	+	$\gamma^a/$	+	$\gamma^b/$	$\gamma^c/$
$E(Y_2)$	+	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 $\rho < \beta_\sigma$.

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 setup costs. Also, in the case where the major barriers to adoption are risk aversion and setup 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 setup costs, adoption is unaffected.

As Propositions 1 and 2 demonstrate, 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, setup costs, or risk aversion--will influence the efficiency response to price support policies.

Proposition 3: Crop Insurance or Price Stabilization for a New Crop. 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 setup costs; farmer welfare is unaffected if the major barriers to adoption are credit and setup 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.

Proposition 4: Crop Insurance or Price Stabilization for an Existing Crop. 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 setup costs; farmer well-being is unaffected in the case where the major barriers to adoption are credit and setup 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 setup costs, the well-being of each individual farmer improves according to the expected utility criterion; but only the large, partially 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 setup costs, the minimum scale required for adoption is decreased while the maximum size of fully adopting farms is increased so that overall adoption increases.

Propositions 3 and 4 clearly reveal 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 5: Extension. The effect of extension activities that improve farmers' subjective distributions of returns under the new technology 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, 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.

These propositions, in the context of the six classes of farmers identified by (26) and (27), 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.

6. Equity Effects of Agricultural Policies

Propositions 1 through 5 focus on the efficiency effects of various policies. However, these propositions along with the proofs also provide the needed results to sort out the equity effects of various policies.

The marginal effects of each policy on individuals in each group are clear from Table 3. In the case of each policy, each group is affected in the same direction as the overall efficiency if it is affected at all. The only unaffected groups, besides cases where aggregate efficiency is also unaffected, are nonadopters in the cases of price support for only the new crop.

A crucial issue in policy analysis is the effect on equity. For purposes of this paper, a policy is said to spread income distribution if, for every pair of farmers, the difference in their certainty equivalent is no smaller after the change than before it and the difference is larger for at least one pair. A policy is said to contract income distribution if, for every pair of farmers, the difference in certainty equivalent is no larger and is smaller for at least one pair.

To see whether policy effects are larger or smaller for more well-off individuals, Table 8 derives $\partial^2 \bar{U}_i / \partial L \partial y$ where y represents some policy instrument. Because farm size ultimately determines income in the model of this paper, income distribution spreads (contracts) if $\partial^2 \bar{U}_i / \partial L \partial y > (<) 0$ over all farm sizes in the farm size distribution.

As the following propositions reveal, every policy considered here will spread income distribution in the low-correlation case if at least one farmer exists in each group. Thus, a benchmark is introduced to determine the degree to which income distribution is spread; namely, farm size is considered as a standard of comparison for change in certainty equivalent among farmers. In this context, cases are found where some policies spread the distribution of certainty equivalent relative to farm size (certainty equivalent per hectare) and other policies contract this distribution.

To see how changes in policy affect the distribution of $\bar{U}_i / L$, first note that

$$\frac{\partial(\bar{U}_i / L)}{\partial y} = \frac{\partial \bar{U}_i}{\partial y} \frac{1}{L} \quad (34)$$

which can be obtained by dividing the entries of Table 3 by L . The slope of (34) with respect to farm size is derived in Table 9 using the identity

$$\frac{\partial^2(\bar{U}_i / L)}{\partial L \partial y} = \frac{\partial^2 \bar{U}_i}{\partial L \partial y} \frac{1}{L} - \frac{\partial \bar{U}_i}{\partial y} \frac{1}{L^2}.$$

The results of Tables 3, 8, and 9 thus prove Propositions 6 through 10.

TABLE 8

Farm size/case						
Y	U_{11}	U_{12}	U_{13}	U_{21}	U_{22}	U_{23}
			$-\partial^2 U_{ij} / \partial \lambda \partial Y$			
m_1	$a/$	1	$\frac{dL_1^*}{dL} < 1$		$\frac{a}{w} > 1$	1
σ_1		$-(2 - \eta)B\sigma_1 L^{1-\eta} < 0$	$\gamma_1^b/$			
m_0	1		$1 - \frac{dL_1^*}{dL} \geq 0$	1	$1 - \frac{a}{w} < 0$	
σ_0	$-(2 - \eta)B\sigma_0 L^{1-\eta}$		$\gamma_2^b/$			
$\bar{p}$		$\frac{dm_1}{dp} - (2 - \eta)B\sigma_1 L^{1-\eta} \frac{d\sigma_1}{dp} > 0$	$\gamma_3^c/$		$\frac{a}{w} \frac{dm_1}{dp} > 0$	$\frac{dm_1}{dp} > 0$
$\bar{p}$	$\gamma_4 > 0$	$\frac{dm_1}{dp} - (2 - \eta)B\sigma_1 L^{1-\eta} \frac{d\sigma_1}{dp} > 0$	$\gamma_5^c/$	$\delta_m \frac{dm_1}{dp} > 0$	$\left[\frac{a}{w} (1 - \delta_m) + \delta_m \right] \frac{dm_1}{dp} > 0$	$\frac{dm_1}{dp} > 0$
$\bar{\sigma}$	$-(2 - \eta)B\sigma_0 L^{1-\eta} \frac{d\sigma_1}{d\sigma} > 0$	$-(2 - \eta)B\sigma_1 L^{1-\eta} \frac{d\sigma_1}{d\sigma} > 0$	$\gamma_6^b/$			

(Continued on next page.)

TABLE 8 continued.

a/ Blanks indicate zero.

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

$$\gamma_1 = -\phi\sigma_0 L_1 - \phi[(2\sigma_1 - \rho\sigma_0) - L_1 + \rho\sigma_0 L_0] \frac{dL_1}{dL} < 0 \text{ if } R > 0$$

$$\gamma_2 = -\phi(2\sigma_0 L_0 + \rho\sigma_1 L_1) + \phi[(2\sigma_0 - \rho\sigma_1) L_0 + \rho\sigma_1 L_1] \frac{dL_1}{dL} < 0 \text{ if } R > 0$$

$$\gamma_3 = nZ_1 L^{\eta-1} + R_V \frac{dm}{dp} + \frac{2a}{\sigma_1} \frac{1}{133(2-n)} R_V L^{1-h} \frac{d\sigma_1}{dp} > 0 \text{ if } R_V > 0$$

$$\gamma_4 = \beta_m \frac{dm}{dp} - (2-n)B\sigma_0\beta_\sigma L^{1-\eta} \frac{d\sigma_1}{dp} > 0$$

$$\gamma_5 = nZ_2 L^{\eta-1} + Z_3 + (2-n)Z_4 L^{1-\eta} > 0 \text{ if } R_V > 0$$

$$\gamma_6 = nZ_6 L^{\eta-1} + (2-n)Z_7 L^{1-\eta} < 0 \text{ if } R_V > 0$$

$$\frac{dL_1}{dL} = R(1-n) + \frac{nL_1}{L} > 0 \text{ if } R > 0.$$

Proposition 6: Price Support for a New Crop or Extension Activities.

Suppose the new technology pertains to the existing crop and that an effective price support is instituted, that an existing price support is increased, or that extension activities are instituted or increased to improve farmers' subjective distribution (mean and/or variance) of returns. If risk and setup costs are the major barriers to adoption, then the certainty equivalent is unaffected for nonadopters, increases more than in proportion to farm size for full adopters, and increases less than in proportion to farm size for partial adopters. If at least some farms are adopters and if correlation is low or no farmers are partial adopters, income distribution spreads. If all farmers are either nonadopters or full adopters (with at least some full adopters), then the distribution of the certainty equivalent relative to farm size spreads; however, if all farmers are partial adopters, then this distribution contracts in the high-correlation case.

If credit and setup costs are the major barriers to adoption, then an increase in price support will cause the certainty equivalent to be unaffected for nonadopters, to increase less than in proportion to farm size for partial adopters, and to increase in proportion to farm size for full adopters. If at least some farmers are adopters, then income distribution spreads. Unless all farmers are nonadopters or all farmers are full adopters, the distribution of the certainty equivalent relative to farm size spreads.

Proposition 7: Price Support for an Existing Crop. Suppose the new technology pertains to the existing crop and that either an effective price support is instituted or an existing price support is increased. If risk and setup costs are the major barriers to adoption, then the certainty equivalent increases among nonadopters in an amount increasing in farm size, increases

among full adopters more than in proportion to farm size, and increases among partial adopters (in an amount that is increasing in farm size in the low-correlation case). Income distribution spreads either if no farmers are partial adopters or if correlation is low. If all farmers are either non-adopters or full adopters, then the distribution of the certainty equivalent relative to farm size spreads; however, if all farmers are partial adopters, then this distribution contracts in the low risk aversion case, $B \leq \zeta$ (see Table 9).

If credit setup costs are the major barriers to adoption, then the certainty equivalent increases among nonadopters and full adopters by an amount proportional to farm size (although the proportion is greater among full adopters than among nonadopters) and increases among partial adopters by an amount more than proportional to farm size. Income distribution spreads regardless of farm size distribution. Unless all farmers are nonadopters or all farmers are full adopters, the distribution of certainty equivalent relative to farm size spreads.

Proposition 8: Crop Insurance or Price Stabilization for a New Crop.

Suppose the new technology pertains to the new crop and that either an actuarially fair crop insurance program is instituted or prices stabilize at the mean. If risk and setup costs are the major barriers to adoption, then the certainty equivalent is unaffected among nonadopters, increases among full adopters more than in proportion to farm size, and increases among partial adopters more (less) than in proportion to farm size if correlation is low (high), i.e.,

$$R > (<) \frac{L_1^2 (\rho\sigma_0 - \sigma_1)}{2L_1 L (\rho\sigma_0 - \sigma_1) - \rho\sigma_0 L^2} .$$

TABLE 9

Y	Farm size/case					
	U_{11}	U_{12}	U_{13}	U_{21}	U_{22}	U_{23}
	----- $\partial^2(U_{ij}/L)/\partial L \partial Y$ -----					
m_1	0	0	$\frac{1}{L} \left(\frac{dL_1^*}{dL} - \frac{L_1^*}{L} \right) < 0$	0	$\frac{k}{wL^2} > 0$	0
σ_1	0	$(\eta - 1) B\sigma_1 L^{-\eta} < 0$	w_1	0	0	0
m_0	0	0	$\frac{1}{L} \left(\frac{L_1^*}{L} - \frac{dL_1^*}{dL} \right) > 0$	0	$-\frac{k}{wL^2} < 0$	0
σ_0	$(\eta - 1) B\sigma_0 L^{-\eta} < 0$	0	w_2	0	0	0
$\bar{p}$	0	$(\eta - 1) B\sigma_1 L^{-\eta} \frac{d\sigma_1}{d\bar{p}} > 0$	w_3	0	$\frac{k}{wL^2} \frac{dm_1}{d\bar{p}} > 0$	0
$\bar{p}$	$(\eta - 1) B\sigma_0 \sigma_0 L^{-\eta} \frac{d\sigma_1}{dp} > 0$	$(\eta - 1) B\sigma_1 L^{-\eta} \frac{d\sigma_1}{dp} > 0$	w_4	0	$(1 - \beta_m) \frac{k}{wL^2} \frac{dm_1}{dp} > 0$	0
$\bar{\sigma}$	$(\eta - 1) B\sigma_0 \sigma_0 L^{-\eta} \frac{d\sigma_1}{d\sigma} < 0$	$(\eta - 1) B\sigma_1 L^{-\eta} \frac{d\sigma_1}{d\sigma} < 0$	w_5	0	0	0

(Continued on next page.)

TABLE 9--continued.

$$W_1 = \frac{\phi(1-\eta)}{L^2} [L_1 (2LR - L_1) (\rho\sigma_0 - \sigma_1) - \rho\sigma_0 L^2 R] \geq 0$$

$$\text{as } R \leq \frac{L_1^2(\rho\sigma_0 - \sigma_1)}{2L_1 L(\rho\sigma_0 - \sigma_1) - \rho\sigma_0 L^2}$$

$$(W_1 > 0 \text{ if } R \leq 0; W_1 < 0 \text{ if } R = 1)$$

$$W_2 = \frac{d(1-\eta)}{L^2} [(1-R) \{2L_0 L(\rho\sigma_1 - \sigma_0) - \rho\sigma_1 L^2\} - L_0^2(\rho\sigma_1 - \sigma_0)] \geq 0$$

$$\text{as } R \geq \frac{2L_0 L(\rho\sigma_1 - \sigma_0) - \rho\sigma_1 L^2 - L_0^2(\rho\sigma_1 - \sigma_0)}{2L_0 L(\rho\sigma_1 - \sigma_0) - \rho\sigma_1 L^2}$$

$$(W_2 > 0 \text{ if } R = 1; W_2 < 0 \text{ if } R = 0)$$

$$W_3 = \frac{1}{L} \left(\frac{dL_1^*}{dL} - \frac{L_1^*}{L} \right) \frac{dm_1}{dp} + z_1 \frac{d\sigma_1}{dp} < 0 \quad \text{if } W_1 \geq 0$$

$$W_4 = \frac{1-\eta}{L^2} \left\{ -2a_{131} \frac{1-\beta_m}{E(\Delta\pi)} \frac{dm_1}{dp} + \frac{1}{\sigma} \left[\frac{E^2(\Delta\pi)}{BV(\Delta\pi)} + BR^2 V(\Delta\pi) - B\sigma_0^2 \right] \frac{d\sigma_1}{dp} \right\} < 0$$

$$\text{if } B \leq \frac{E(\Delta\pi)}{\sqrt{[\sigma_0^2 - R^2 V(\Delta\pi)] V(\Delta\pi)}} \equiv \zeta > 0$$

$$W_5 = \frac{1-\eta}{\sigma_1 L^2} \left[\frac{E^2(\Delta\pi)}{BV(\Delta\pi)} - BR^2 V(\Delta\pi) - B\sigma_0^2 \right] \frac{d\sigma_1}{d\sigma} \geq 0 \quad \text{as } B \geq \zeta > 0$$

As long as not all farmers are nonadopters, income distribution spreads in the case of low correlation ($\rho < \sigma_0/\sigma_1$). If all farmers are either nonadopters or full adopters (with at least some full adopters) or if correlation is low, as defined by (35), with at least some adopters, then the distribution of the certainty equivalent relative to farm size spreads; however, if all farmers are partial adopters and correlation is high, as defined by (35), then this distribution contracts.

Proposition 9: Crop Insurance or Price Stabilization for an Existing Crop. Suppose the new technology pertains to the existing crop and that either an actuarially fair crop insurance is instituted or prices stabilize at the mean. If risk and setup costs are the major barriers to adoption, then the certainty equivalent increases among nonadopters in an amount more than proportional to farm size, increases among full adopters more than in proportion to farm size, increases in a proportion greater than that for nonadopters, and increases among partial adopters in an amount more (less) than proportional to farm size if risk aversion is high (low), i.e., $B > (<) \zeta$ (see Table 9). If all farms are either nonadopters or full adopters or if correlation is low ($\rho < \sigma_0/\sigma_1$), then income distribution spreads. If all farmers are either nonadopters or full adopters or if risk aversion is high ($B > \zeta$), then the distribution of the certainty equivalent relative to farm size spreads; however, if all farmers are partial adopters and risk aversion is low ($B < \zeta$), then this distribution contracts (see Table 9).

Proposition 10: Extension. Suppose Extension activities that improve farmers' subjective distributions of returns under the new technology are instituted or increased. If risk and setup costs are the major barriers to adoption, then the certainty equivalent is unaffected for nonadopters; it

increases more than in proportion to farm size for full adopters; and it increases less than in proportion to farm size for partial adopters. If at least some farms are adopters and if correlation is low or no farmers are partial adopters, income distribution spreads. If all farmers are either nonadopters or full adopters (with at least some full adopters), then the distribution of the certainty equivalent relative to farm size spreads; however, if all farmers are partial adopters, then this distribution contracts in the high-correlation case.

If credit and setup costs are the major barriers to adoption, then an increase in price support will cause the certainty equivalent to be unaffected for nonadopters, to increase less than in proportion to farm size for partial adopters, and to increase in proportion to farm size for full adopters. If at least some farmers are adopters, then income distribution spreads. Unless all farmers are nonadopters or all farmers are full adopters, the distribution of the certainty equivalent relative to farm size spreads and, among nonadopters, increases more than in proportion to farm size among full adopters.

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, propositions have been derived which reveal many insights for policy analysis. However, to operationalize these propositions, a considerable 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 the vector of expected returns defined by technology, the variances and covariances of returns defined across technologies, the variable cost of new inputs, the opportunity cost of financial funds, the fixed setup costs of various technologies, and available credit.

Estimated relationships between the above explanatory variables and discrete technology choices and continuous land allocation choices are 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 these four empirical components, a number of operational uses of the proposed framework are possible. First, one 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 utilized heavily in isolating those trade-offs which allow a set of scalar criterion functions to be examined by parametric analysis. When such criterion 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 perform effectively 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 trade-offs 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.

Footnotes

*These materials are compiled from several papers coauthored with Gordon C. Rausser and David Zilberman.

¹See Just and Zilberman for discussion of other cases.

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