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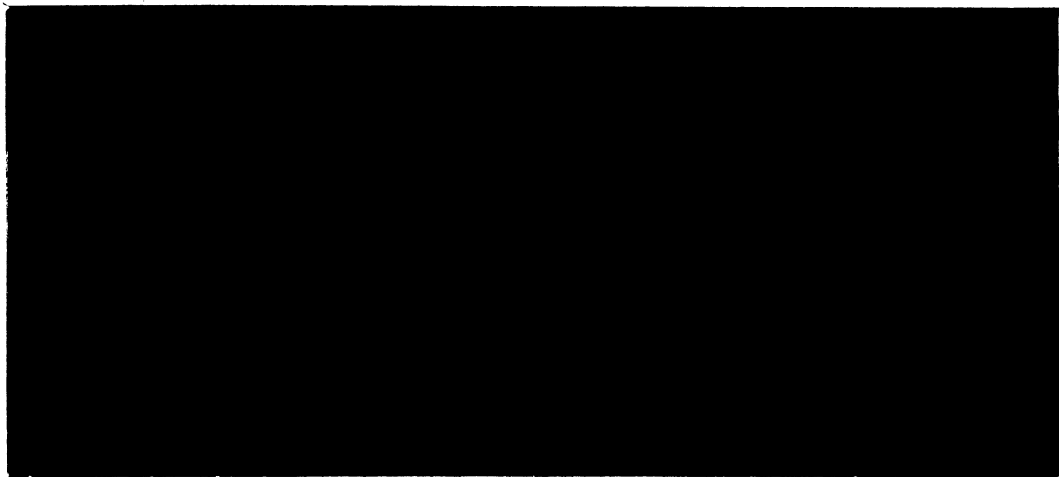
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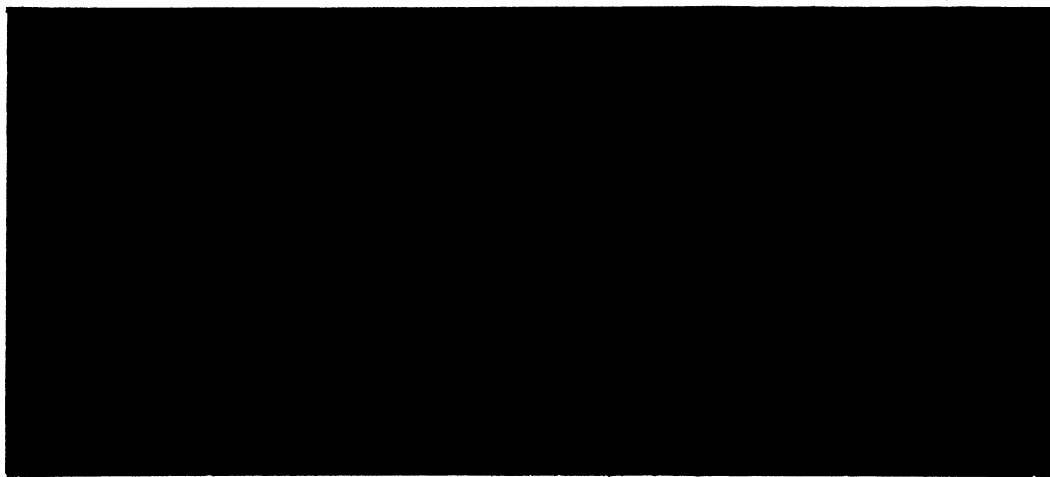
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THE ROLE OF AGRICULTURAL PRICE SUPPORTS AND LAND  
CONTROLS IN TECHNOLOGICAL ADOPTION UNDER UNCERTAINTY --

by

Eithan Hochman, Gordon C. Rausser, Richard E. Just, and David Zilberman

California Agricultural Experiment Station  
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IN TECHNOLOGICAL ADOPTION

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# THE ROLE OF AGRICULTURAL PRICE SUPPORTS AND LAND CONTROLS IN TECHNOLOGICAL ADOPTION

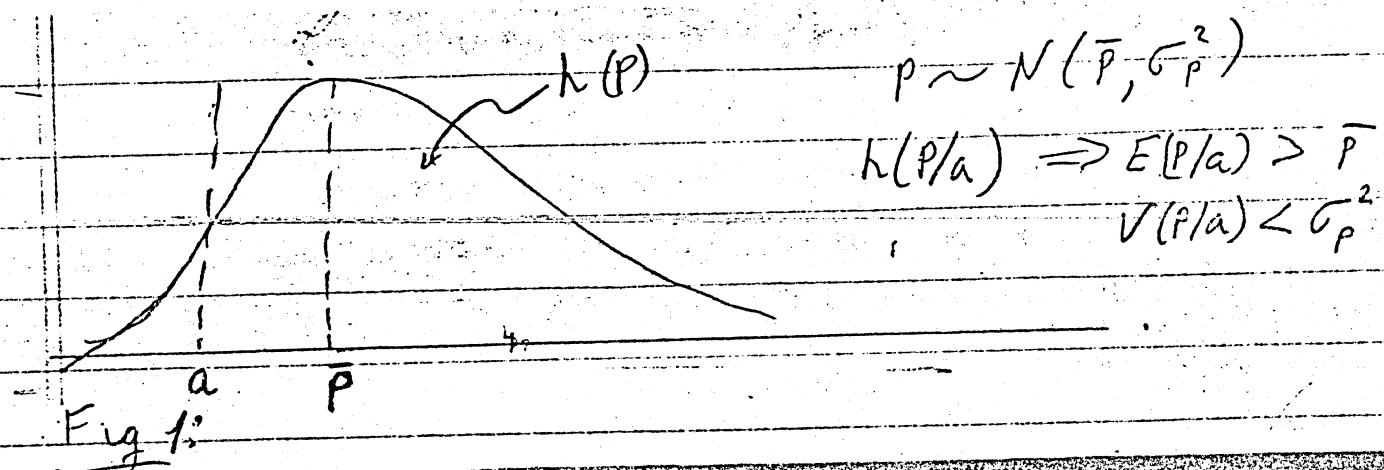
## Introduction

[ In this paper, we specifically consider the impact of price-support programs in a stylized model of one crop and two technologies--a traditional and a modern--adopting the framework developed earlier by Just, Zilberman, and Rausser. Within this framework, we analyze the effects of price-support programs on the rate of adoption of a new technology in the case of yield-increasing technology. The results are then extended to include the more realistic cases of diversion and price-support programs with two crops, each characterized by its own production technology and market environment. The model is then extended to include the credit and cash constraints the farmer faces as well as initial and second-round effects of changes in the output of the industry. Finally, some general qualitative results are offered for the effects of policy mixes, including price supports, acreage set-asides, and deficiency payments on technological adoption. ]

## 2. The Stylized Model: Impact of Price Support Programs on Technological Adoption with One Crop

In this simplified model, some of the most important features are clearly depicted. An individual farmer is faced with uncertainty both in price and output (Bacon) and must make decisions on the rate of adoption of a new output-increasing technology. Government intervention, in the form of price supports, affects the price-distribution parameters, location and dispersion, i.e., increasing conditional mean and reducing the conditional price dispersion of the price-probability distribution as depicted in figure 1.

Figure 1



We consider the effects of a price support, say,  $\tilde{P}$ , on the farmers' responses within the context of the following model:

$$(2.1) \max_{L_1, L_2} \bar{z}_1 L_1 + \bar{z}_2 L_2 - \phi (Var z_1 L_1^2 + Var z_2 L_2^2 - 2 L_1 L_2 Cov z_1 z_2)$$

subject to:

$$L_1 + L_2 = \bar{L}$$

where

$z_i = P_i$  is the per unit land profit from technology  $i$ ,

$\bar{L}$  is the fixed landholding

$L_1$  is land allocated to the traditional technology

$L_2$  is land allocated to the modern technology

and

$$(2.2) \begin{bmatrix} z_1 \\ z_2 \end{bmatrix} \sim N \left[ \begin{pmatrix} \bar{z}_1 \\ \bar{z}_2 \end{pmatrix}, \begin{pmatrix} Var z_1 & Cov z_1 z_2 \\ Cov z_1 z_2 & Var z_2 \end{pmatrix} \right]$$

Since there is only one crop, the distribution of price is the same with mean  $\bar{P}$  and variance  $\sigma_p^2$ . The output distributions are different under the two technologies, i.e.,

$$\begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix} \sim \left[ \begin{pmatrix} \bar{\lambda}_1 \\ \bar{\lambda}_2 \end{pmatrix}, \begin{pmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{pmatrix} \right] \text{ where } \begin{matrix} i=1 \text{ is the old technology} \\ i=2 \text{ is the new technology} \end{matrix}$$

The solution for the optimal land capacity devoted to the new technology is,

$$(2.3) L_2^* = \frac{\bar{z}_2 - \bar{z}_1 + 2 \phi \bar{L} (Var z_1 - Cov z_1 z_2)}{2 \phi (Var z_1 + Var z_2 - 2 Cov z_1 z_2)}$$



The assumption of gradual adoption by the farmer is based on the observation that in many cases the new technology, which is embodied in specific equipment, will be tried first on some of the lots owned by the farmer, and the diffusion of its use will vary according to the characteristics of the cultivated land and crop.

As noted, the above simplified model serves in focusing on issues that are crucial in more realistic formulations. We start by investigating the way the specific distribution parameters are introduced into the model.

The profits the farmer receives, i.e., the random variables  $z_i$ , are the product of the two random variables: price times output, i.e.,  $p\lambda_i$ . Thus, before evaluating the impact of price-support programs within our model (which may require additional assumptions in order to obtain meaningful results), it is of interest to consider the relations between price and output for a given technology.

Let the farmer's profit be  $z_i = p\lambda_i$ . Then

$$(2.4) \quad E z_i = E(p\lambda_i) = \bar{p}\bar{\lambda}_i + \text{Cov } p\lambda_i = \bar{p}\bar{\lambda}_i + \sum_{i=1,2} \sigma_p \sigma_{\lambda_i}$$

and as Goldbert has shown

$$(2.5) \quad \text{Var } z_i = A + B + C + D + F + G$$

where

$$A = \bar{\lambda}_i \sigma_p^2 \quad ; \quad B = \bar{p}^2 \sigma_{\lambda_i}^2 \quad ; \quad C = 2\bar{p}\bar{\lambda}_i \text{Cov } p\lambda_i = 2\bar{p}\bar{\lambda}_i \sigma_p \sigma_{\lambda_i}$$

$$D = E \left[ (p - \bar{p})(\lambda_i - \bar{\lambda}_i) - \text{Cov } p\lambda_i \right]^2 \quad ;$$

$$F = 2\bar{p} E \left[ (p - \bar{p})(\lambda_i - \bar{\lambda}_i)^2 \right] \quad \text{and}$$

$$G = 2\bar{\lambda}_i E \left[ (p - \bar{p})^2 (\lambda_i - \bar{\lambda}_i) \right].$$

We note that, in the case of dependence between the distributions of price and output, the expected value of profit involves an additional term,  $\text{Cov}(P\lambda_i)$ . This term can have the following interpretation: even though the individual farmer is a pricetaker, he has the information that exogenous shocks to the industry (e.g., draught or specifically favorable weather conditions, pesticides, and sudden spread of regional diseases, etc.) may change the output of the whole industry, via the law of demand, i.e., negative slope between price and quantity bought results in a negative correlation between price and output and, if he operates rationally, he may take it into account.

Now, the effect of a price-support program on the expected value of profit will be to increase it, since

$$\frac{dE Z_i}{d\bar{p}} = \bar{\lambda}_i \frac{d\bar{p}}{d\bar{p}} + \beta \sigma_i \frac{d\bar{p}}{d\bar{p}}$$

where

$$\frac{d\bar{p}}{d\bar{p}} > 0, \quad \frac{d\bar{p}}{d\bar{p}} < 0 \quad \text{and} \quad \beta < 0.$$

As for the effect of price support on  $\text{Var } Z_i$ , it can be verified that two opposite effects operate: the effect on A is to decrease the variance, while the effect on B is to increase it. The effect on C has both a reducing effect through  $2\bar{\lambda}_i P_0 \sigma_i \frac{d\sigma_p}{d\bar{p}} > 0$ . As for the effect of the remaining three terms, it is hard to evaluate, and Burt and Finley claim in their empirical work that they found a substantial reduction in the error involved by omitting terms, D, F, and G, when the "variance was measured around a trend instead of around the mean of the time series" (p. 156).

Note, also, that the variance can be rewritten after a few calculations and algebraic manipulation:

$$(2.6) \text{Var } z_i = \bar{P}^2 \sigma_i^2 + \bar{\lambda}_i^2 \sigma_p^2 + \sigma_p^2 \sigma_i^2 - \bar{P} \bar{\lambda}_i \sigma_p \sigma_i \left[ 2 + \beta \frac{\sigma_p}{\bar{P}} \cdot \frac{\sigma_i}{\bar{\lambda}_i} \right] + \text{Cov}(P^2 \lambda_i^2)$$

In this formulation, if we make the reasonable assumption that  $\text{Cov}(P^1 \lambda_i^2)$ --which is of a higher order--can be ignored, then the increasing and decreasing effects of price support on the variance can be explicitly calculated.

In the case that the price and output distributions are independent of the above quantities, take the following relatively simple expressions:

$$E z_i = \bar{P} \lambda_i \quad \text{and} \quad \text{Var } z_i = \bar{P}^2 \sigma_i^2 + \bar{\lambda}_i^2 \sigma_p^2 + \sigma_p^2 \sigma_i^2$$

The essential directions of the impact of price-support programs do not change, i.e., expected value of profit is increased and the impact on the variance includes two opposite effects--the effect on  $\bar{P}$  is to increase the variance of profit and the effect on  $\sigma_p^2$  is to decrease it. However, the expressions are much simpler as a result of the assumption  $\text{Cov}(P, \lambda_i) = 0$ , and the two effects can be calculated separately.

The assumption of  $\text{Cov}(P \lambda_i) = 0$  can be justified when:

a. The crop in the region is only a small portion of the total supply and, hence, random changes in the regional output will not influence price.

b. If the productivity technology is such that no big fluctuations are expected because of weather conditions and other exogenous random shocks. A controlled irrigated agricultural system may serve as an example.

c. The farmer does not take into account the random interaction between price and output, following the reasoning of bounded rationality.

During the analysis in this section, we assume  $\text{Cov } P\lambda_i = 0$  and, hence, we have

$$E z_i = \bar{z}_i = \bar{P} \bar{\lambda}_i; \text{Var } z_i = \bar{P}^2 \sigma_i^2 + \bar{\lambda}_i^2 \sigma_P^2 + \sigma_P^2 \sigma_i^2$$

$$(2.7) \quad \text{Cov } z_1, z_2 = \sigma_P^2 (\sigma_{12} + \bar{\lambda}_1 \bar{\lambda}_2) + \bar{P}^2 \sigma_{12} \quad \text{and}$$

$$E(z_2 - z_1) = \bar{z}_2 - \bar{z}_1 = \bar{P}(\bar{\lambda}_2 - \bar{\lambda}_1) = \bar{P} m.$$

We shall assume  $m > 0$ , i.e., the second technology is yield increasing unless it is explicitly assumed otherwise.

Price-support program,  $\tilde{P}$ , results in

$$\frac{d\bar{P}}{d\tilde{P}} > 0 \quad \text{or} \quad \frac{d\bar{P}^2}{d\tilde{P}} > 0 \quad \text{and} \quad \frac{d\sigma_P}{d\tilde{P}} < 0 \quad \text{or} \quad \frac{d\sigma_P^2}{d\tilde{P}} < 0.$$

In this section, two extreme cases will be considered:

a. The case where the two technologies have independent distributions, i.e.,  $\sigma_{12} = \rho_{12} \sigma_1 \sigma_2 = 0$ .

b. The case where  $\text{Cov } z_1 z_2 = 1$ . This result is obtained (either when both outputs, say,  $\lambda_1$ , and  $\lambda_2^*$  are deterministic<sup>1</sup>) or when the following linear case holds:

$$z_1 = g_1 \varepsilon, \quad z_2 = g_2 \varepsilon \quad \text{and} \quad \varepsilon \sim N(0, \sigma^2).$$

Note that in the yield-increasing case,  $g_2 > g_1$ . The solution for optimal land allocation to the modern technology can be rewritten from (2.3):

$$(2.8) \quad L_2^* = \frac{\bar{z}_2 - \bar{z}_1}{2\phi V} + \bar{L} \frac{W}{V}$$

where

$$W = \text{Var } Z_1 - \text{Cov } Z_1 Z_2$$

$$V = \text{Var } Z_1 + \text{Var } Z_2 - 2 \text{Cov } Z_1 Z_2.$$

In the case a ( $\sigma_{12} = 0$ ):

$$\bar{z}_2 - \bar{z}_1 = \bar{P}(\bar{\lambda}_2 - \bar{\lambda}_1) = \bar{P}m;$$

$$(2.9) \quad W = \bar{P}^2 \sigma_1^2 + \sigma_P^2 (\sigma_1^2 - \bar{\lambda}_1 m) \quad \text{and}$$

$$V = \bar{P}^2 (\sigma_1^2 + \sigma_2^2) + \sigma_P^2 (\sigma_1^2 + \sigma_2^2 + m^2).$$

In case b ( $\text{Cov } Z_1 Z_2 = 1$ )

$$\bar{z}_2 - \bar{z}_1 = (g_2 - g_1)\mu = g\mu; \quad \text{Var } z_1 = g_1^2 \sigma^2, \quad \text{Var } z_2 = g_2^2 \sigma^2$$

$$\text{Cov } z_1 z_2 = g_1 g_2 \sigma^2 \quad \text{and}$$

$$\text{Corr } z_1 z_2 = \frac{\text{Cov } z_1 z_2}{\sqrt{\text{Var } z_1 \text{Var } z_2}} = \frac{g_1 g_2 \sigma^2}{g_1 g_2 \sigma^2} = 1$$

$$W = g_1^2 \sigma^2 - g_1 g_2 \sigma^2 = -\sigma^2 g_1 g_2$$

$$V = \sigma^2 (g_1^2 + g_2^2 - 2g_1 g_2) = \sigma^2 g^2$$

Thus,

$$\frac{W}{V} = -\frac{g_1}{g} = \text{negative constant.} \quad \text{and}$$

$$(2.10) \quad L_2^* = \frac{\mu}{2\phi g \sigma^2} - \bar{L} \frac{g_1}{g}$$

Or, in the deterministic outputs case,

$$L^* = \frac{\bar{P}}{2\phi \lambda^* \sigma^2} - \bar{L} \frac{\lambda_1^*}{\lambda^*} \quad \text{where } \lambda^* = \lambda_2^* - \lambda_1^*$$

REMARK 1: Note that the LHS of (2.8) consists of two terms: the first term includes the risk premium of the yield-increasing technology. It will increase the contribution of the first term to a larger  $L_2^*$ --the larger the difference between the corresponding means of the profits, the smaller the variance of this difference and the smaller is the risk-aversion coefficient. The second term measures the opportunity costs of adopting the new technology in terms of farm size. In case b it has always a negative contribution to  $L_2^*$ , while in case a it usually has a positive contribution (sufficient condition is  $\sigma_1^2 > \lambda_1 m$ ). Also, the second term does not depend on the risk-aversion coefficient,  $\phi$ , and, hence, a decrease in this coefficient will always increase  $L_2^*$ .

The following propositions will focus on the impact of price-support programs in the two extreme cases. However, the behavior in the range of possible alternatives between these two cases can be deduced.

PROPOSITION 1: For the given distribution of the price of the crop and its output from old and new technology, the impact of a price support will always increase the amount of land devoted to the new technology if there is unit correlation between the profits of the two technologies. However, in other cases, especially when the covariance between the output of the two technologies decreases, it is possible that  $L_2^*$  will decrease as a result of price support. The range of such cases depends on the specific parameters of price output distribution.

In the extreme case of zero covariance between the outputs of the two technologies ( $s_{12} = 0$ ), sufficient conditions for  $dL_2^*/dp > 0$  are:

$$0 < \frac{\sigma_1^2 + \sigma_2^2}{\sigma_1^2 + \sigma_2^2 + m^2} < \frac{-\frac{d\sigma_p^2}{d\bar{p}}}{\frac{d\bar{p}^2}{d\bar{p}}} < \frac{\sigma_1^2}{\sigma_1^2 - \lambda_1 m} > 1$$

PROOF: In the case of unit correlation between the profits, i.e., case b, it can be easily verified from (2.10) that  $dL_2^*/d\tilde{p} > 0$ , since  $d\mu/d\tilde{p} > 0$ ,  $d\sigma^2/d\tilde{p} < 0$ , and all the rest of the parameters are not affected by  $\tilde{p}$ .

In the case of zero covariance between outputs ( $\sigma_{12} = 0$ ), we note that from (2.8) and (2.9):

$$\frac{dL_2^*}{d\tilde{p}} = \frac{m\bar{p}}{2\phi V} \left[ \frac{1}{\bar{p}} \frac{d\bar{p}}{d\tilde{p}} - \frac{1}{V} \frac{dV}{d\tilde{p}} \right] + \left[ \frac{W}{V} \left[ \frac{1}{W} \frac{dW}{d\tilde{p}} - \frac{1}{V} \frac{dV}{d\tilde{p}} \right] \right]$$

where

$$\frac{1}{V} \frac{dV}{d\tilde{p}} = \frac{1}{\bar{p}^2} \frac{d\bar{p}^2}{d\tilde{p}} v_1 + \frac{1}{\sigma_p^2} \frac{d\sigma_p^2}{d\tilde{p}} v_2$$

$$v_1 = \frac{\bar{p}^2 (\sigma_1^2 + \sigma_2^2)}{\bar{p}^2 (\sigma_1^2 + \sigma_2^2) + \sigma_p^2 (\sigma_1^2 + \sigma_2^2 + m^2)} ; v_2 = \frac{\sigma_p^2 (\sigma_1^2 + \sigma_2^2 + m^2)}{\bar{p}^2 (\sigma_1^2 + \sigma_2^2) + \sigma_p^2 (\sigma_1^2 + \sigma_2^2 + m^2)}$$

$$v_1 + v_2 = 1 \quad \Rightarrow v_1, v_2 > 0$$

$$\frac{1}{W} \frac{dW}{d\tilde{p}} = \frac{1}{\bar{p}^2} \frac{d\bar{p}^2}{d\tilde{p}} w_1 + \frac{1}{\sigma_p^2} \frac{d\sigma_p^2}{d\tilde{p}} w_2$$

$$w_1 = \frac{\bar{p}^2 \sigma_1^2}{\bar{p}^2 \sigma_1^2 + \sigma_p^2 (\sigma_1^2 - \bar{\lambda}_1, m)} ; w_2 = \frac{\sigma_p^2 (\sigma_1^2 - \bar{\lambda}_1, m)}{\bar{p}^2 \sigma_1^2 + \sigma_p^2 (\sigma_1^2 - \bar{\lambda}_1, m)}$$

$$w_1 + w_2 = 1$$

$$1 > w_1 > 0 \quad \text{and} \quad 1 > w_2 > 0 \Rightarrow \frac{\sigma_1^2 + \bar{\lambda}_1^2}{\bar{\lambda}_1} > \bar{\lambda}_2$$

$$\frac{1}{V} \frac{dV}{d\tilde{p}} < 0 \quad \text{and} \quad \frac{1}{W} \frac{dW}{d\tilde{p}} > 0 \Rightarrow \frac{dL_2^*}{d\tilde{p}} > 0$$

Sufficient condition for  $1/v \, dV/dp < 0$  is,

$$-\frac{\frac{d\sigma_p^2}{d\tilde{p}}}{\frac{d\tilde{p}^2}{d\tilde{p}}} > \frac{\sigma_1^2 + \sigma_2^2}{\sigma_1^2 + \sigma_2^2 + m^2} > 0$$

Sufficient conditions for  $1/w \, dW/dp > 0$  is,

$$-\frac{\frac{d\sigma_p^2}{d\tilde{p}}}{\frac{d\tilde{p}^2}{d\tilde{p}}} < \frac{\sigma_1^2}{\sigma_1^2 - \lambda_1 m^2} > 1$$

REMARK 1: Note the following:

i. Given the yield's distribution parameters  $(\bar{\lambda}_1, \bar{\lambda}_2, \sigma_1^2, \sigma_2^2)$ , if the ratio  $(-d\sigma_p^2/d\tilde{p})/(d\tilde{p}^2/d\tilde{p})$  is smaller than unity, then the higher is the absolute change in  $\sigma_p^2$  wrt  $\tilde{p}$  and the lower is the absolute change in  $\tilde{p}^2$  wrt  $\tilde{p}$  and the more likely is the possibility that  $1/v \, dV/d\tilde{p}$  will be negative and, hence, tend to create and also increase positive  $dL_2^*/d\tilde{p}$ .

ii. If  $(d\sigma_p^2/d\tilde{p})/(d\tilde{p}^2/d\tilde{p}) > 1$ , then the lower bound is not effective, but there is an upper bound which changes  $1/n \, dw/d\tilde{p}$  into a negative quantity and, hence, has a negative effect on  $dL_2/d\tilde{p}$  even though  $dL_2^*/d\tilde{p}$  may still be positive.

REMARK 2: (i) An increase in  $\mu$ , other things being equal, will strengthen the positive effect in  $dL_2^*/d\tilde{p}$ , the same impact will have also an increase in  $\bar{d}_2$  alone, in the case  $\bar{d}_1$ , it will have a positive effect if accompanied by a parallel increase in  $\bar{d}_2$  such that  $\mu$  will remain constant.



(ii) A decrease in either  $\sigma_1^2$  or  $\sigma_2^2$  will increase the range of the bounds for  $dL_2^*/d\tilde{p} > 0$ .

REMARK 3: Table 1 indicates directions of impacts of the price and yields distribution parameters on  $dL_2^*/d\tilde{p}$ , assuming  $1/v \, dv/d\tilde{p} < 0$  and  $1/w \, dw/d\tilde{p} > 0$ .

REMARK 4: In case b, the unit correlation takes away the benefits from diversification and the gains from price support though the conditional price distribution are larger for the new technology than for the old one.

In CASE A, the results depend on the relations between the specific distribution parameters as shown in Proposition 1.

From equation (2.8), it follows that there are linear relations between  $L_2^*$  and  $\bar{L}$ , and the intercept of this function includes the risk aversion. In the following propositions, we investigate the impact of price support on these relations focusing on the farm size ( $\bar{L}$ ) and risk attitude ( $\phi$ ).

PROPOSITION 2: For a given distribution of the price of crop and the crop yields under the two technologies, the impact of price support in the case of unit correlation between profits from the two technologies in a neutral upward shift of  $L_2^*$  as a linear function of  $\bar{L}$  (though the slope is negative), and (ii) in the case of zero covariance between yields of the two technologies will result in an increase in the positive slope if the coefficient of variation of the old technology multiplied by the standard deviation of the new one is greater than the coefficient of variation of the new technology multiplied by the standard deviation of the old one; also, an upward shift in the intercept will result if the variance of the profit mean difference is reduced by the price support, i.e.,

$$\frac{d(L_2^*/\bar{L})}{d\tilde{p}} > 0$$

if

$$\sigma_2 \frac{\bar{\lambda}_1}{\sigma_1} > \sigma_1 \frac{\bar{\lambda}_2}{\sigma_2}$$

where  
is (i)?

TABLE 1: Effects on  $dL_2^*/d\tilde{p}$  assuming  $1/v \, dv/d\tilde{p} < 0$  and  $1/w \, dw/d\tilde{p} > 0$ .

Increase in:	Increase in $\frac{dL_2^*}{d\tilde{p}}$ via	Decrease in $\frac{dL_2^*}{d\tilde{p}}$ via
$\bar{p}^2$	$w_1 \uparrow \quad w_2 \downarrow$	$v_1 \uparrow \quad v_2 \downarrow$
$\sigma_p^2$	$v_1 \downarrow \quad v_2 \uparrow$	$w_1 \downarrow \quad w_2 \uparrow$
$m$	$v_1 \downarrow \quad v_2 \uparrow \quad w_1 \uparrow \quad w_2 \downarrow$	_____
$\bar{\lambda}_2 \Rightarrow m \uparrow \Rightarrow$	" " " "	
$\bar{\lambda}_1$	but $(-\bar{\lambda}_1, m/m_0) \Rightarrow w_1 \uparrow \quad w_2 \downarrow$	$m \downarrow$
$\sigma_1^2$	_____	$v_1 \uparrow \quad v_2 \downarrow \quad w_1 \downarrow \quad w_2 \uparrow$
$\sigma_2^2$	_____	$v_1 \uparrow \quad v_2 \downarrow$ _____

2.16 a

and

$$\frac{d\left(\frac{\bar{p}m}{2\phi V}\right)}{d\bar{p}} > 0 \quad \text{if} \quad \frac{1}{V} \frac{dV}{d\bar{p}} < 0.$$

PROOF: In CASE A, introduce (2.9) into (2.8) and differentiate to obtain,

$$\frac{dL_2}{d\bar{L}} = \frac{W}{V} = \frac{\bar{p}\sigma_1^2 + \sigma_p^2(\sigma_1^2 - \bar{\lambda}_1 m)}{\bar{p}^2(\sigma_1^2 + \sigma_2^2) + \sigma_p^2(\sigma_1^2 + \sigma_2^2 + m^2)}.$$

? The differentiate with respect to  $\bar{p}$ ,

$$\frac{d\left[\frac{dL_2}{d\bar{L}}\right]}{d\bar{p}} = \frac{W}{V} \left[ \frac{1}{W} \frac{dW}{d\bar{p}} - \frac{1}{V} \frac{dV}{d\bar{p}} \right].$$

where

$$\frac{1}{W} \frac{dW}{d\bar{p}} - \frac{1}{V} \frac{dV}{d\bar{p}} = \frac{1}{\bar{p}^2} \frac{d\bar{p}^2}{d\bar{p}} (w_1 - v_1) + \frac{1}{\sigma_p^2} \frac{d\sigma_p^2}{d\bar{p}} (w_2 - v_2)$$

$w_1, w_2, v_1$ , and  $v_2$  are defined in Proposition 1.

Let

$$D = [\bar{p}^2\sigma_1^2 + \sigma_p^2(\sigma_1^2 - \bar{\lambda}_1 m)] [\bar{p}^2(\sigma_1^2 + \sigma_2^2) + \sigma_p^2(\sigma_1^2 + \sigma_2^2 + m^2)]$$

Then,

$$w_1 - v_1 = \frac{1}{D} \sigma_p^2 \bar{p}^2 m (\bar{\lambda}_1 \sigma_2^2 + \bar{\lambda}_2 \sigma_1^2) > 0$$

and

$$w_2 - v_2 = -\frac{1}{D} \sigma_p^2 \bar{p}^2 m (\bar{\lambda}_1 \sigma_2^2 - \bar{\lambda}_2 \sigma_1^2) \leq 0 \text{ if } \sigma_2 \frac{\bar{\lambda}_1}{\sigma_1} \geq \sigma_1 \frac{\bar{\lambda}_2}{\sigma_2}$$

Hence, a sufficient condition for

$$\frac{d\left(\frac{dL_i^*}{d\bar{L}}\right)}{d\tilde{P}} > 0 \quad \text{is} \quad \sigma_2 \frac{\bar{\lambda}_1}{\sigma_1} > \sigma_1 \frac{\bar{\lambda}_2}{\sigma_2}.$$

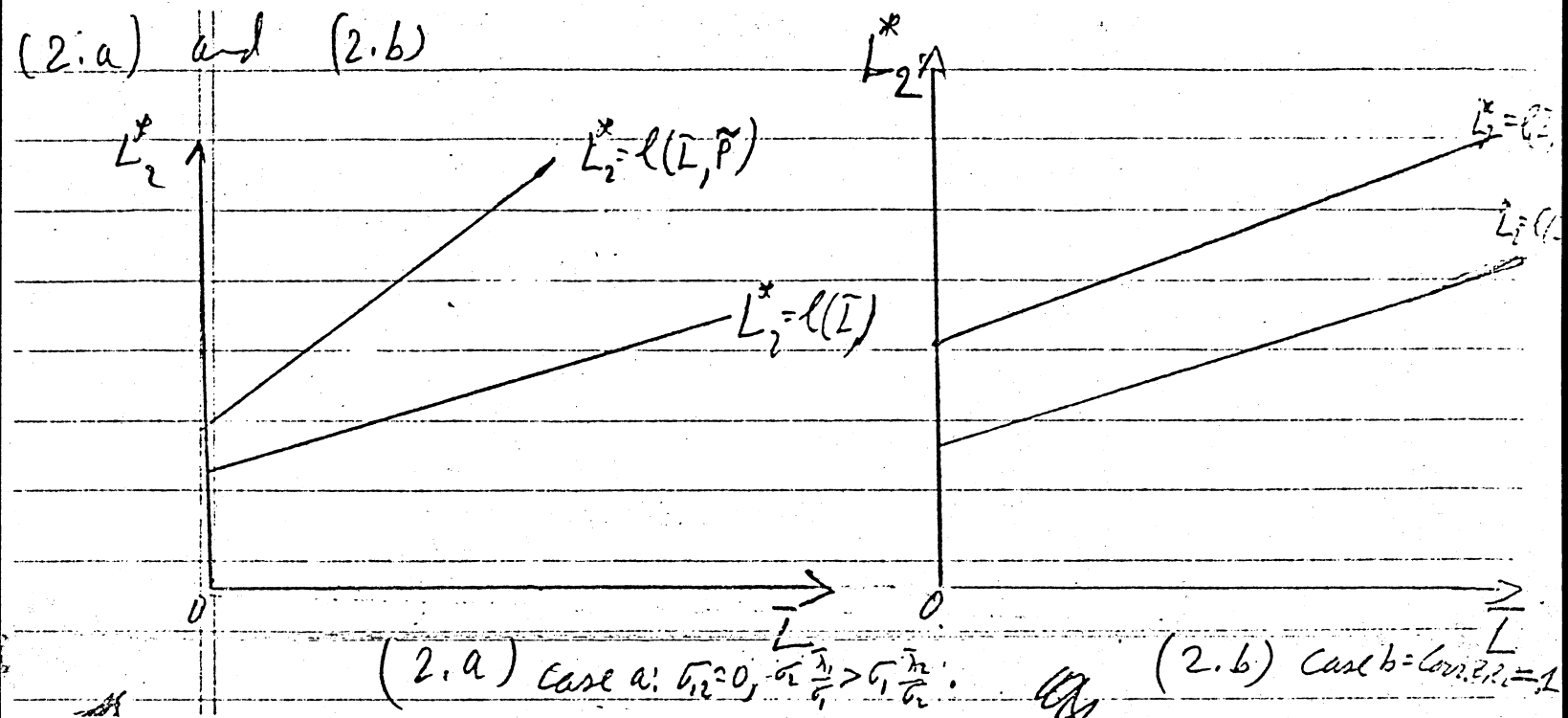
In CASE B, from equation (2.10)

$$\frac{dL_2^*}{d\bar{L}} = -\frac{g_1}{g} \Rightarrow \frac{d\left(\frac{dL_2^*}{d\bar{L}}\right)}{d\tilde{P}} = 0$$

REMARK 1: Here, too, the results are intuitively plausible. The increase in  $\bar{L}$  leads to greater variance of profits and diversification by using some of each increment of land under each technology is a way to reduce the variance of the profits. However, as pointed out above [pp. 2.11, 2.12, equation (2.10) and Remark 1], an increase in  $\bar{L}$  will reduce  $L_2^*$  in the case of unit correlation between profits, i.e., the farmer is inclined to lean more heavily toward the tried and proven old technology. Nevertheless, the reduction of variance by the price-support program will encourage the use of the new technology in both cases in the ways described in figures (2.a) and (2.b).

In the case of covariance zero between yields ( $\sigma_{12} = 0$ ), the results depend on the specific parameters of the price and output distributions. If  $\sigma_2 \bar{\lambda}_1 / \sigma_2 > \sigma_1 \bar{\lambda}_2 / \sigma_2$  holds, we know that the farmers will increase the use of the new technology, and the larger farms will tend to be more inclined to use the reduction in risk and adopt the new technology (the increase is both in the slope and intercept). In CASE B, the reduction in risk by the price support will always favor the new technology with greater yield but a more risky one; but, since there is no advantage in diversification, the increase in  $L_2^*$  is neutral, i.e., through an upward shift in the intercept alone as depicted in figure (2.b).

Figures 2.a and 2.b.



PROPOSITION 3: For a given distribution of the price of crop and the crop yields under the two technologies, the relative share of the new technology is decreasing in farm size. Price-support programs will reduce the rate of decrease, i.e.,  $\frac{d\left[\frac{d(L_2^*)}{d\bar{L}}\right]}{d\bar{P}} < 0$ , always in the case of unit

correlation between profits and in the case of zero covariance between yields,  $1/V \, dV/d\bar{P} < 0$ , is a sufficient condition for this decrease.

PROOF: From equation (2.8), divide  $L_2^*$  by  $\bar{L}$  and differentiate with respect to  $\bar{L}$  to obtain:

$$\frac{d\left(\frac{L_2^*}{\bar{L}}\right)}{d\bar{L}} = - \frac{\bar{Z}_2 - \bar{Z}_1}{\bar{L}^2 2\phi V} < 0$$

In CASE A

$$\frac{d\left[\frac{d(L_2^*)}{d\bar{L}}\right]}{d\bar{P}} = - \frac{\bar{P}_m}{\bar{L}^2 2\phi V} \left( \frac{1}{\bar{P}} \frac{d\bar{P}}{d\bar{P}} - \frac{1}{V} \frac{dV}{d\bar{P}} \right) < 0 \text{ if } \frac{1}{V} \frac{dV}{d\bar{P}} < 0$$

In CASE B

$$\frac{d\left[\frac{d(L_2^*)}{d\bar{L}}\right]}{d\bar{P}} = - \frac{M}{2\phi g \sigma^2} \left[ \frac{1}{M} \frac{dM}{d\bar{P}} - \frac{1}{\sigma^2} \frac{d\sigma^2}{d\bar{P}} \right] < 0$$

*Heading?* The adoption with various land endowments considering varying fixed costs in CASES A and B.

Following section 4 where  $\bar{U}_2$ ,  $\tilde{U}_2$ ,  $\bar{L}^*$ ,  $\bar{L}^+$ ,  $\tilde{L}^+$ , and  $\hat{L}$  are defined in equations (13) to (19) and investigated graphically in figures 1 and 2, the impact of price-support programs is considered here.

In the case of  $\bar{L}^*$  where modern technology is adopted first and the critical value of  $\bar{L}^*$  determines the transformation to the region of using both technologies, we noticed that, in both CASES A and B, the impact of price support will be to increase the width of the range of the first stage where only the new modern technology is adopted, i.e.,  $d\bar{L}^*/d\bar{P} > 0$ .

PROOF:

$$\bar{L}^* = \frac{\bar{z}_2 - \bar{z}_1}{2\phi (\text{Var } z_2 - \text{Cov } z_1, z_2)}$$

CASE A:

$$\bar{L}^* = \frac{\bar{p} m}{2\phi X}$$

where

$$X = \bar{p}^2 \sigma_z^2 + \sigma_p^2 (\sigma_z^2 + \bar{\lambda}_2 m)$$

$$\frac{d\bar{L}^*}{d\tilde{p}} > 0 \quad \text{since} \quad \frac{m d\bar{p}}{d\tilde{p}} > 0 \quad \text{and}$$

$$\frac{dX}{d\tilde{p}} = \sigma_z^2 \frac{d\bar{p}^2}{d\tilde{p}} + (\sigma_z^2 + \bar{\lambda}_2 m) \frac{d\sigma_p^2}{d\tilde{p}} < 0 \quad \text{if} \quad \frac{\frac{d\sigma_p^2}{d\tilde{p}}}{\frac{d\bar{p}^2}{d\tilde{p}}} > \frac{\sigma_z^2}{\sigma_z^2 + \bar{\lambda}_2 m} < 1$$

which covers all reasonable scenarios.

$$\bar{L}^* = \frac{\mu}{2\phi \sigma^2 g_2}$$

CASE B:

$$\frac{d\bar{L}^*}{d\tilde{p}} > 0 \quad \text{since} \quad \frac{d\mu}{d\tilde{p}} > 0 \quad \text{and} \quad \frac{d\sigma^2}{d\tilde{p}} < 0 \quad \square$$

Next, we follow the generalization of the relationships to the case of endogenous adoption decisions and distinguish in our two cases (CASE A is covariance zero between yield, and CASE B is the unit correlation between profits) and deal in each of them with low- and high-fixed costs of the new technology. In the putty-clay context, the old technology's fixed costs can

be considered as sunken funds (or opportunity costs of fixed capital zero) or the fixed costs of new technology can be measured as a net over those of the old technology, i.e.,  $k = k_2 - k_1$  where 1 and 2 are the old and new technologies, respectively.

? CASE A:  $s_{12} = 0$ , relevant c.v.  $\bar{L}^+$  and  $\bar{L}^+$  in figures 2.a and 2.b.

### I. Low fixed costs

Let,

$$\begin{aligned} Y &= \text{Var} z_2 - \text{Var} z_1 = \bar{p}^2 \sigma_2^2 + \bar{\lambda}_2^2 \sigma_p^2 + \sigma_p^2 \sigma_2^2 - \bar{p}^2 \sigma_1^2 - \bar{\lambda}_1^2 \sigma_p^2 - \sigma_p^2 \sigma_1^2 \\ &= (\sigma_2^2 - \sigma_1^2) \left[ \bar{p}^2 + \sigma_p^2 \left( 1 + \frac{\bar{\lambda}_2^2 - \bar{\lambda}_1^2}{\sigma_2^2 - \sigma_1^2} \right) \right] > 0. \end{aligned}$$

and from equation 17 in Just et al, p. 12, obtain in our case,

$$\bar{L}^+ = \frac{1}{2\phi Y} \left[ \bar{p} m - \sqrt{\bar{p}^2 m^2 - 4\phi k Y} \right]$$

where  $k$  is the fixed cost assumed to be relatively low, where  $U_1$  intersects  $\bar{U}_2$  (from above) to the left of  $\bar{L}^*$ .

The impact of  $\bar{p}$  on  $\bar{L}^+$  consists of various effects operating in opposite directions.

Denote

$$A_1 = \frac{1}{2\phi Y} \text{ and } B_1 = \left[ \bar{p} m - \sqrt{\bar{p}^2 m^2 - 4\phi k Y} \right]$$

$$\frac{dA_1}{d\bar{p}} > 0 \iff \frac{dY}{d\bar{p}} < 0 \iff -\frac{\frac{d\sigma_p^2}{d\bar{p}}}{\frac{d\bar{p}^2}{d\bar{p}}} > \frac{1}{1 + \frac{\bar{\lambda}_2^2 - \bar{\lambda}_1^2}{\sigma_2^2 - \sigma_1^2}} < 1$$



A sufficient condition for

$$\frac{dB_1}{d\tilde{p}} = \left(1 - \frac{2\tilde{p}m}{\sqrt{\tilde{p}^2m^2 - 4\phi k y}}\right) m \frac{d\tilde{p}}{d\tilde{p}} + \frac{4\phi k}{\sqrt{\tilde{p}^2m^2 - 4\phi k y}} \frac{dy}{d\tilde{p}} < 0$$

is  $\frac{dy}{d\tilde{p}} < 0$ .

$$\frac{d\bar{L}^+}{d\tilde{p}} = B_1 \frac{dA_1}{d\tilde{p}} + A_1 \frac{dB_1}{d\tilde{p}}$$

The total effect can be calculated,

the first term has a positive effect and, hence, shifts  $\bar{L}^*$  to the right, and the second effect has a negative effect and, hence, shifts  $\bar{L}^+$  to the left.

The net effect depends on the relative strength of each of the separate effects.

Note that, in this, the impact of price support on the dispersion of the price distribution relative to its impact on the location of the price is larger than the bound  $1/1 + r_{12}$ , and the coefficient  $r_{12} = \lambda_2 - \lambda_1/\sigma_2^2 - \sigma_1^2$  is the net risk premium of the new technology.

In this case, price support will tend to reduce the difference between the variance of the profit from the new technology and the variance of the profit from old technology and, hence, encourage adoption of the new technology, i.e.,  $dA_1/d\tilde{p} > 0$ . But, at the same time, the impact of price support on the term that measures the net contribution of the new technology after deducting for the fixed costs of adoption is to reduce the rate of adoption, i.e.,  $dB_1/d\tilde{p} < 0$ . Also, the higher the fixed cost coefficient,  $k$ , the stronger the influence of the second term and, hence, reducing the encouragement of adoption of new technology by price support.

Now, in case that the ratio between the impact of price support on dispersion with respect to location of the price distribution is smaller than the bound  $1/1 + r_{12} < 1$ , the impact of the price-support program on the

difference between the two profit variances will be to increase  $dY/d\tilde{p} > 0$  and, hence, to discourage adoption of new technology, i.e.,  $dA_1/d\tilde{p} < 0$ . However, in the second term,  $dB_1/d\tilde{p}$  (it) will consist of two opposite effects where the part which includes the fixed costs coefficient,  $k$ , will have a positive effect on  $dB_1/d\tilde{p}$ . Thus, the impact of an increase in the fixed costs will change and its effect on the price-support program will be to encourage adoption of modern technology, i.e., it will strengthen the forces shifting  $\bar{L}^+$  to the right.

## II. High Fixed Costs

$$\bar{L}^+ = \frac{1}{2\phi w} [\sqrt{4\phi k v} - \bar{p}m]. \quad C+P$$

Let,

$$A_2 = \frac{1}{2\phi w} \quad \text{and} \quad B_2 = [\sqrt{4\phi k v} - \bar{p}m].$$

Under the assumption of proposition 1 where  $dw/d\tilde{p} > 0$  and  $dv/d\tilde{p} < 0$ , we obtain  $dA_2/d\tilde{p} < 0$  and  $dB_2/d\tilde{p} < 0$  and, hence,  $d\bar{L}/d\tilde{p} < 0$ . Thus, the effect of price support will be to decrease the range of using the old technology and, hence, encourage adoption of the new technology while using the old one at smaller farm sizes, i.e., lower  $\bar{L}$ . Note that an increase in  $k$  will increase the impact of price support in the direction pointed above.

Note, however, that, if  $dw/d\tilde{p} < 0$ , i.e., if

$$-\frac{\frac{d\sigma_1^2}{d\tilde{p}}}{\frac{d\tilde{p}^2}{d\tilde{p}}} > \frac{\sigma_1^2}{\sigma_1^2 - \lambda m} \quad \left( \frac{dv}{d\tilde{p}} < 0 \text{ a fortiori} \right)$$

$dA_2/d\tilde{p}$  will change its sign to a positive one; and the effect of  $dA_2/d\tilde{p}$  will be opposite to that of  $dB_2/d\tilde{p}$ .

CASE B: Unit profits correlation, i.e.,  $\text{corr } z_1 z_2 = 1$ , relevant critical values  $\bar{L}^+$  and  $\hat{L}$ , (figure 2.c).

In comparing  $\bar{L}^+$  to its value in CASE A, we note:

$$\bar{L}^+ = \frac{1}{\sigma^2 2\phi(q_2^2 - q_1^2)} \left[ \mu g - \sqrt{\mu^2 g^2 - 4\phi k \sigma^2 (q_2^2 - q_1^2)} \right]$$

By inspection, it can be verified that it can be verified that it will always be the case where  $dA_1/dp > 0$  and  $dB_1/dp < 0$ ; and, hence, the analysis that was carried under these conditions is relevant here also.

The critical value of equating  $U_1$  and  $U_2$  is, in this case,

$$\hat{L} = \frac{\mu}{2\phi g_1 \sigma^2} - \sqrt{\frac{k}{\phi}} \cdot \frac{1}{g_1 \sigma} = \frac{1}{\phi g_1} \left[ \frac{\mu}{2\sigma^2} - \sqrt{k\phi} \frac{1}{\sigma} \right]$$

and the impact of price support can be calculated from

$$\frac{d\hat{L}}{d\tilde{p}} = \frac{1}{\phi g_1} \left[ \frac{d\left[\frac{\mu}{2\sigma^2}\right]}{d\tilde{p}} + \sqrt{k\phi} \frac{1}{\sigma^2} \frac{d\sigma}{d\tilde{p}} \right]$$

The first term in the brackets has a positive sign, and hence, the shift in  $\hat{L}$  contributed by this term is to the right; but the sign of the second term is negative and its contribution is to the left. The final outcome depends on the relative strength of the absolute values of these two terms.

Note, however, that the fixed costs coefficients,  $k$ , appears only in the second term. Thus, an increase in fixed costs will tend to strengthen the

Figure 2.c

effect in the impact of price support that tends to shift  $\hat{L}$  to the left and, hence, decrease the range in which the modern technology is applied.

PROPOSITION 3: For given critical values of  $\hat{L}^+$ ,  $\hat{L}^-$ ,  $\hat{L}^*$  and  $\hat{L}$ , the effect of price-support programs on the rate of technological adoption rate depends on (1) the covariance between the yields under the old and the new technologies; (2) the relative effects upon the location and dispersion of the price distribution and the net risk premium,  $\lambda_2 - \lambda_1/\sigma_2^1 - \sigma_1^2$ , on the new technology; and (3) the level of the fixed costs of adoption.

In all cases, the price-support programs create effects that operate in opposite directions which depend on these three factors in ways that were analyzed above. The impact of an increase in the fixed costs,  $k$ , on these effects:

(a)  $\sigma_{12} = 0$  and low  $k$  ( $Y = \text{var } Z_2 - \text{var } Z_1$ ).

(i) If  $dy/d\tilde{p} < 0$ , an increase in  $k$  will strengthen the effect in price-support programs that contributes to the decrease of the rate of adoption of new and modern technology.

(ii) If  $dy/d\tilde{p} > 0$ , an increase in  $k$  will strengthen the effect in price-support programs that contributes to the increase of the rate of adoption of new and modern technology.

(b)  $\sigma_{12} = 0$  and high  $k$ .

(i) Under the assumptions of proposition 1, i.e.,

$$\frac{dW}{d\tilde{p}} > 0 \text{ and } \frac{dV}{d\tilde{p}} < 0, \quad \frac{d\tilde{L}^+}{d\tilde{p}} < 0 \text{ always.}$$

(ii) If  $dW/d\tilde{p} < 0$  ( $dV/d\tilde{p} < 0$  a fortiori), the sign of  $d\tilde{L}^+/d\tilde{p}$  is negative or positive according to the relative strength of the two opposite effects as discussed above.

In both cases, an increase in  $k$  will result in strengthening the effect of price support that increases the range over smaller size farms that will adopt the new technology.

REMARK: The last result has the following intuitive explanation. To the left of  $L^+$  there are farmers that the high costs of investment prevent from adopting the new technology. The effect of the price-support program is to reduce the variance of the difference between the two yields, i.e.,  $dV/d\tilde{P} < 0$ , and, hence, those farmers facing a new situation where the gains from diversification were increased by the reduction in  $V$  will adopt.

This explains, also, the third case:

(iii) If  $dV/d\tilde{P} > 0$  ( $dV/d\tilde{P} > 0$  a fortiori), the sign, if  $d\tilde{L}^+/d\tilde{P}$  as in the second case, is not determined. Effects in both directions exist but some of the signs of these effects are reversed. In particular, now, an increase in  $k$  will result in strengthening the effect of price support that decreases the range of  $I$  over which farmers will adopt the new technology such that only larger farmers will adopt. Again, this result is consistent with the previous remark.

(c)  $\text{Cov } Z_1 Z_2 = 1$ .

An increase in  $k$  will have a mitigating effect on the impact of price support on adoption of the new technology; hence, fewer farmers both near  $\bar{L}^+$  and  $\hat{L}$  will be joining the region of adoption.

### 3. Two Crops, Each with Its Own Price and Output Distribution

In this section we extend the framework of the previous section to include the case of two crops, each characterized by its own price distribution and its production technology with its random output.

Following the notation of the previous section, let

$z_1$  be the profit from the first crop and

$z_2$  be the profit from the second crop

Assume that  $\bar{z}_2 - \bar{z}_1 = m > 0$  and  $\sigma_2^2 - \sigma_1^2 > 0$ .

The specification of the model in Section 2 holds, and

$$(3.1) \quad L_2^* = \frac{m}{2\phi V} + \bar{L} \frac{W}{V}$$

where

$$W = \sigma_1^2 - \sigma_{12} = \sigma_1 \sigma_2 \left( \frac{\sigma_1}{\sigma_2} - \rho \right)$$

$$V = \sigma_1^2 + \sigma_2^2 - 2\sigma_{12} = \sigma_1 \sigma_2 \left( \frac{\sigma_1}{\sigma_2} - \rho \right) + \sigma_1 \sigma_2 \left( \frac{\sigma_2}{\sigma_1} - \rho \right)$$

We assume, first, that the price-support program results in the same rate of change in variances (or standard deviations) of the profits, i.e.,

$$\text{i.e.} \quad \frac{1}{\sigma_1} \frac{d\sigma_1}{d\tilde{p}} = \frac{1}{\sigma_2} \frac{d\sigma_2}{d\tilde{p}} = \eta_{\sigma\tilde{p}} \quad (3.2)$$

Note that CASE B in the previous section (the linear case and deterministic yields) can be considered as a special case of equal rates of change in the variances.

We assume, also, that

(3.3) We assume also,  $\frac{d\bar{E}_1}{d\tilde{P}} > 0$ ,  $\frac{d\bar{E}_2}{d\tilde{P}} > 0$ ,  $\frac{dm}{d\tilde{P}} > 0$  and  $\tau_{\tilde{P}} < 0$ .  
 $L_1 + L_2 = \bar{L}$  and  $\frac{dP}{d\tilde{P}} = 0$ .

PROPOSITION 5: For a given subjective distribution of profits per acre, price-support programs will increase the land allocated to the second crop and reduce the land allocated to the first crop.

PROOF: To prove  $dL_2/d\tilde{P} > 0$ , we first prove  $[d(W/V)]/d\tilde{P} = 0$ .

$$(a) \quad \frac{dW}{d\tilde{P}} = \left[ \sigma_2 \left( \frac{\sigma_1}{\sigma_2} - \beta \right) + \sigma_1 \right] \frac{d\sigma_1}{d\tilde{P}} + \left[ \sigma_1 \left( \frac{\sigma_1}{\sigma_2} - \beta \right) - \frac{\sigma_1^2}{\sigma_2} \right] \frac{d\sigma_2}{d\tilde{P}} =$$

$$= 2\tau_{\tilde{P}} W < 0$$

$$(b) \quad \frac{dV}{d\tilde{P}} = \left[ \sigma_2 \left( \frac{\sigma_1}{\sigma_2} - \beta \right) + \sigma_1 + \sigma_2 \left( \frac{\sigma_1}{\sigma_1} - \beta \right) - \frac{\sigma_2^2}{\sigma_1} \right] \frac{d\sigma_1}{d\tilde{P}} +$$

$$+ \left[ \sigma_1 \left( \frac{\sigma_1}{\sigma_2} - \beta \right) - \frac{\sigma_1^2}{\sigma_2} + \sigma_1 \left( \frac{\sigma_2}{\sigma_1} - \beta \right) + \sigma_2 \right] \frac{d\sigma_2}{d\tilde{P}} =$$

$$= 2\tau_{\tilde{P}} V$$

$$(3.4) \quad \frac{d\left[\frac{W}{V}\right]}{d\tilde{P}} = \frac{W}{V} \left[ \frac{1}{W} \frac{dW}{d\tilde{P}} - \frac{1}{V} \frac{dV}{d\tilde{P}} \right] = 0$$



Thus,

$$(3.5) \quad \frac{dL_2^*}{d\tilde{P}} = \frac{m}{2\phi V} \left[ \frac{1}{m} \frac{dm}{d\tilde{P}} - \frac{1}{V} \frac{dV}{d\tilde{P}} \right] > 0$$

since

$$\frac{dV}{d\tilde{P}} < 0 \text{ and } \frac{dm}{d\tilde{P}} > 0,$$

the proof that  $dL^*/dP < 0$  follows immediately, from the condition  $L^* + L^* = L$ .

REMARK 1: Proposition 5 is intuitively obvious since the price-support program favors both expected profits of the second crop,  $dm/dP > 0$ , and imposing equal rates of change the price dispersion of the second crop, which is the more risky one, benefits. Later in this section, relaxing some of the assumptions and/or changing them will be considered.

PROPOSITION 6: For a given subjective distribution of profits per acre, the results obtained in Propositions 2 and 3 for CASE B hold, also, for the case of equal rates of change in profit dispersion resulting from the price-support program.

PROOF: The contemporary of Proposition 2:

$$(3.6) \quad \frac{d\left(\frac{L_2^*}{L}\right)}{d\tilde{P}} = \frac{d\left[\frac{W}{V}\right]}{d\tilde{P}} = 0 \quad \text{from (3.4)}$$

The contemporary of Proposition 3:

$$(3.7) \frac{d \left[ \frac{dL^*}{d\tilde{p}} \right]}{d\tilde{p}} = \frac{d \left[ -\frac{m}{v} \right]}{d\tilde{p}}, \quad \frac{1}{L^2} = \frac{dL^*}{d\tilde{p}} \cdot \frac{1}{L^2} < 0$$

from Proposition 5.

      . The Impact of Price-Support Programs on the Decisions About the Shares of the Two Crops with Various Farm Sizes and with Endogenous Technologies

In the Just, Raussier, and Zilberman (JRZ) paper, the graphical relationships of the adoption rate of endogenous technologies are depicted with focus on the role of land endowments. In this context, some of the analysis ~~at the end of the previous section~~ was pursued for the case of one crop.

Here, we consider endogenous decisions about the shares of each of the two crops. Note that the JRZ paper assumes that only the technology of the second crop that is assumed to use a more modern or recent technology has fixed costs while the first crop, which uses an old technology, involves zero fixed costs (or, the fixed costs are considered sunken funds). This assumption may be extended to assume  $k = k_2 - k_1 > 0$ , where  $k_i$  are the fixed costs for crop  $i$ .

Using the results obtained in Section 4 of the JRZ paper, the following propositions may be derived for the case of

PROPOSITION 7i: Price-support programs will increase the range of growing crop two if, for  $0 < L^* < \bar{L}^*$ , we have  $L^* = 0$ . (See pages 17-19 in JRZ.)

PROOF:

$$\bar{L}^* = \frac{m}{2\phi(\sigma_1^2 - \sigma_2^2)} \text{ from Eq. (16) in 1.17 in J-R-Z.}$$

Thus,

$$\frac{d\bar{L}^*}{d\tilde{p}} = \bar{L}^* \left( \frac{1}{m} \frac{dm}{d\tilde{p}} - 2\eta_{\sigma\tilde{p}} \right) > 0$$

since

$$\text{Since } \frac{dm}{d\tilde{p}} > 0 \text{ and } \eta_{\sigma\tilde{p}} < 0$$

□

REMARK 1: The price-support program shifts  $L^*$  to the right in figure 1.b and, hence, increases the range in which all the land is devoted to crop two.

PROPOSITION 4: In evaluating price-support programs that result in equal rates of change in the profit variances according to various sizes of land endowments, the following two relevant cases with (1) relatively low fixed costs and (2) relatively high fixed costs are perceived.

(1) Low fixed costs, i.e.,  $\underline{L}^+ < \bar{L}^* \left( m^2 > 4\phi k(\sigma_1^2 - \sigma_2^2) \right)$ .

Price-support programs will result in an increase in the share of crop two (with modern and more risky technology), i.e., shift of  $\bar{L}^+$  to the left and  $L^*$  to the right. An increase in  $k$ , other things being equal, will also encourage the adoption of crop two.

(2) High fixed costs, i.e.,

$$(m < 2\sqrt{\phi k V}) \text{ i.e., } \tilde{L}^+ > \bar{L}, \hat{L} > \bar{L}^*$$

(2.1) Low covariance, i.e.,

$$\sigma_1^2 > \sigma_{12}, \text{ and shifts in } \tilde{L}^+$$

and shifts in  $L^+$ .

Price-support programs result in an increase of the share of crop two.

In the case

$$m > \sqrt{\phi k V} \Rightarrow \text{always}$$

and in the case

$$m < \sqrt{\phi k V} \Leftrightarrow \frac{2(\sqrt{\phi k V} - m)}{m} > \left[ \frac{\frac{1}{m} \frac{dm}{d\bar{p}}}{-\epsilon_{\bar{p}}} \right]$$

Price-support programs will result in an increase of the share of crop one:

In the case

$$m < \sqrt{\phi k V} \Leftrightarrow \frac{2(\sqrt{\phi k V} - m)}{m} < \left[ \frac{\frac{1}{m} \frac{dm}{d\bar{p}}}{-\epsilon_{\bar{p}}} \right]$$

(2.2) High covariance, i.e.,

and shifts in  $L^* L$ .

$$(a) \text{ In the case } \sigma_1^2 < \sigma_{12} \text{ and shifts in } \tilde{L}^* \hat{L} \text{ and } \tilde{L}^+$$

$$m < \sqrt{\phi k V} \Leftrightarrow \frac{2(\sqrt{\phi k V} - m)}{m} < \left[ \frac{\frac{1}{m} \frac{dm}{d\bar{p}}}{-\epsilon_{\bar{p}}} \right]$$

the share of crop two will be increased by a price-support program.

(b) In other cases, large-size farms (around  $\hat{L}$ ) will increase the share of crop one while medium-size farms (around  $L^*$ ) will increase the share of crop two.

PROOF:

(a)

$$\bar{L}^+ = \frac{1}{2\phi\gamma} \left[ m - \sqrt{m^2 - 4\phi k\gamma} \right]$$

$$\text{where } \gamma = \sigma_2^2 - \sigma_1^2$$

$$\frac{d\bar{L}^+}{d\tilde{p}} = \frac{1}{2\phi\gamma} \left( 1 - \frac{2m}{\sqrt{m^2 - 4\phi k\gamma}} \right) \frac{dm}{d\tilde{p}} +$$

$$+ \left[ -\frac{1}{2\phi\gamma^2} (m - \sqrt{m^2 - 4\phi k\gamma}) + \frac{4\phi k}{\sqrt{m^2 - 4\phi k\gamma}} \right] \frac{d\gamma}{d\tilde{p}}$$

Note that the first term on the L \_\_\_\_\_ H \_\_\_\_\_

S \_\_\_\_\_ is negative since

$$\frac{dm}{d\tilde{p}} > 0 \text{ and } \left( 1 - \frac{2m}{\sqrt{m^2 - 4\phi k\gamma}} \right) < 0$$

To evaluate the second term on the L \_\_\_\_\_ H \_\_\_\_\_ S \_\_\_\_\_, note that

$$\frac{d\gamma}{d\tilde{p}} = 2\tau_{\sigma\tilde{p}} \gamma < 0$$

and,

$$\left[ \frac{m^2 - m\sqrt{m^2 - 4\phi ky}}{2\phi y \sqrt{m^2 - 4\phi ky}} \right] \tau_{\sigma\tilde{p}} < 0$$

Since

$$\tau_{\sigma\tilde{p}} < 0$$

and

$$m^2 - m\sqrt{m^2 - 4\phi ky} > 0$$

Hence,

$$\frac{d\tilde{L}^+}{d\rho} < 0, \text{ also } \frac{d\tilde{L}^+}{d\tilde{p}} > 0,$$

as proved above.

Thus, the range of adoption of crop two is increased.

It can be verified by inspection that an increase in  $k$  will increase the absolute value of

$$\left| \frac{d\tilde{L}^+}{d\tilde{p}} \right| \cdot \square$$

(b)

$$\tilde{L}^+ = \frac{1}{2\phi W} [\sqrt{4\phi kV} - m] \text{ and } \hat{L} = -\frac{1}{2\phi W} (m - \sqrt{4\phi kV})$$

where

$$W = \sigma_1^2 - \sigma_{12} = \sigma_1 \sigma_2 \left( \frac{\sigma_1}{\sigma_2} - \rho \right),$$

$$W \geq 0 \iff \frac{\sigma_1}{\sigma_2} \geq \rho;$$

$$V = \sigma_1^2 + \sigma_2^2 - 2\sigma_{12} = \sigma_1 \sigma_2 \left( \frac{\sigma_1}{\sigma_2} - \rho \right) + \sigma_1 \sigma_2 \left( \frac{\sigma_2}{\sigma_1} - \rho \right)$$

Note that

$$\frac{1}{W} \frac{dW}{d\tilde{p}} = \frac{1}{V} \frac{dV}{d\tilde{p}} = 2\gamma_{\alpha\tilde{p}}$$

Introducing these results into

$$\frac{d\tilde{L}^+}{d\tilde{p}} \text{ and } \frac{d\hat{L}}{d\tilde{p}}$$

and rearranging terms results in

$$\frac{d\tilde{L}^+}{d\tilde{p}} = \frac{d\hat{L}}{d\tilde{p}} = \frac{1}{2\phi W} [2\gamma_{\alpha\tilde{p}}(m - \sqrt{\phi k V}) - \frac{dm}{d\tilde{p}}]$$

Note that

$$\tilde{L}^+ > 0 \text{ and } \hat{L} > 0 \Rightarrow 2\sqrt{\phi k V} > m.$$

In the case where

$$2\sqrt{\phi k V} > m > \sqrt{\phi k V}$$

both terms in the brackets are negative and, hence,

$$\frac{d\tilde{L}^+}{d\tilde{p}} = \frac{d\hat{L}}{d\tilde{p}} < 0$$

and, from figure 2 in the JRZ paper, we conclude that, since  $L^*$  shifts to the right and  $\tilde{L}^+$  and  $\hat{L}$  shift to the left in the case of low covariance, the share of crop two is increased ( $L^*$  is not binding). In the case of high

covariance (figure 2.c), the shift in  $L^*$  increases the share of crop two but the shift in  $L$  to the left increases the share of crop one.

REMARK 1: Note that, in the case of equal rates of change in the profits as a result of price support: in CASE A, since the yield contribution by crop two is large relative to the fixed costs, the adoption of the modern crop will be encouraged no matter what the fixed costs are. Moreover, the larger  $k$ , the more effective is the price-support program.

In CASE B, the relations between the yield contribution ( $m$ ) and the cost term,

$$\sqrt{\phi k V}$$

are crucial as well as the relations between the ratio

$$\frac{\sigma_1}{\sigma_2} \text{ and } \rho.$$

As long as the correlation term is relatively small,

$$\frac{\sigma_1}{\sigma_2} > \rho$$

if crop two contributes substantially to yield, farmers at land endowments greater than  $L^*$  will tend to adopt the modern but costly technology (crop two) in response to government support. However, if correlation between profits is high, i.e.,

$$\frac{\sigma_1}{\sigma_2} < \rho$$

the response is reversed. If yield increase by adopting crop two is substantial, the large-size farmers will buy more security, additional profit generated by the government support, and diversify by adopting more of crop one.



In the case of low covariance between the two profits, it is of interest to consider the case when the covariance between profits is zero but the previous assumption of equal rates of change of the two variances in response to the price support is relaxed, i.e.,

$$\sigma_{12} = 0 \text{ and } \frac{1}{\sigma_1} \frac{d\sigma_1}{d\tilde{p}} \neq \frac{1}{\sigma_2} \frac{d\sigma_2}{d\tilde{p}}.$$

Thus, the optimal allocated land for crop two is

$$(3.15) \quad L_2^* = v_1 \left[ \frac{m}{2\phi\sigma_1^2} + \bar{L} \right]$$

where

$$v_1 = \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2}, \quad v_2 = \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2} \text{ and } v_1 + v_2 = 1$$

The impact of price-support programs on  $L_2^*$  is

$$(3.16) \quad \frac{dL_2^*}{d\tilde{p}} = \frac{v_1}{2\phi} \cdot \frac{d\left(\frac{m}{\sigma_1^2}\right)}{d\tilde{p}} + \left(\frac{m}{2\phi\sigma_1^2} + \bar{L}\right) \frac{dv_1}{d\tilde{p}}$$

The first term in the L                      H                      S                      is always positive. The second term can have either sign, according to the sign of

$$\frac{dv_1}{d\tilde{p}}.$$

To evaluate the sign, denote

$$R_1 = \frac{1}{\sigma_1^2} \frac{d\sigma_1^2}{d\bar{p}}$$

and

$$R_2 = \frac{1}{\sigma_2^2} \frac{d\sigma_2^2}{d\bar{p}}$$

then,

$$(3.17) \quad \frac{dr_i}{d\bar{p}} \geq 0 \quad \Leftrightarrow \quad |R_1| \leq |R_2|.$$

These results prove the following proposition.

PROPOSITION \_\_\_\_\_. A sufficient but not necessary condition for price-support programs to increase the share of the modern second crop is that price support will result in a greater absolute rate of decrease of variance of the profit of crop two than that of crop one, i.e.,

$$(3.17) \quad |R_1| < |R_2|$$

REMARK: This result is not surprising since the yield-increasing effect [the first in eq. (3.16)] is in favor of crop two. If the inequality in eq. (3.17) is reversed, the risk-reducing effect [the second term in eq. (3.16)] will operate in opposite direction to that of the yield effect until the share of crop two will start to reduce.

Considering the results obtained in Proposition 7 of this section, we note that they apply to the case of zero covariance as well, i.e., the impact of price support is to increase the share of crop two or

$$\frac{d\bar{L}^*}{d\bar{P}} > 0.$$

It is of interest to compare the result in CASES A and B in Proposition 8 with those of the following proposition.

PROPOSITION 6: In the case of zero covariance between profits, the impact of price supports according to various sizes of land endowments and fixed costs can be depicted as follows:

(1) Low fixed costs, i.e.,

$$\bar{L}^+ < \bar{L}^*$$

Price-support programs will encourage the cultivation of crop two through the yield effect. However, their effect, through reducing the risk, depends on the following relative risk ratios:

$$\frac{\sigma_2^2}{\sigma_1^2} \stackrel{\checkmark}{\underset{\checkmark}{<}} \frac{R_1}{R_2}.$$

More specifically, if

$$\frac{k}{\sqrt{m^2 - 4\phi k y}} > \bar{L}^+$$

then

$$\frac{\sigma_2^2}{\sigma_1^2} > \frac{R_1}{R_2}$$

is a sufficient but not necessary condition in this case for the price-support program to increase the share of crop two. On the other hand,

$$\frac{\sigma_2^2}{\sigma_1^2} < \frac{R_1}{R_2}$$

is a necessary but not sufficient condition for a resulting increase in crop one. The effect of an increase in  $k$  is not in one direction and depends on the strength and direction of the yield and risk effects.

(2) High fixed costs, i.e.,

$$\tilde{L}^+ > \bar{L}^*$$

Price-support programs will always increase the share of crop two. An increase in the fixed costs will further encourage the increase in the share of crop two.

PROOF: Note that, given the level of  $\bar{L}^*$ , a shift to the left (right) of  $\bar{L}^+$  in CASE A and of  $\tilde{L}^+$  in CASE B will result in an increase (decrease) in the share of crop two.

(a) The derivative of  $\tilde{L}^+$  with respect to  $\tilde{P}$  can be written after rearranging terms

$$\begin{aligned} (3.18) \quad \frac{d\tilde{L}^+}{d\tilde{P}} &= \frac{1}{2\phi\gamma} \left\{ \left( 1 - \frac{m}{\sqrt{m^2 - 4\phi k\gamma}} \right) \frac{dm}{d\tilde{P}} + \right. \\ &\quad \left. + \left[ \frac{4\phi k}{2\sqrt{m^2 - 4\phi k\gamma}} - \frac{1}{\gamma} (m - \sqrt{m^2 - 4\phi k\gamma}) \right] \cdot \frac{d\gamma}{d\tilde{P}} \right\} \\ &= \frac{1}{2\phi\gamma} \left[ \tilde{A} \frac{dm}{d\tilde{P}} + \tilde{B} \frac{d\gamma}{d\tilde{P}} \right] \end{aligned}$$

$$\tilde{A} < 0 \quad \text{since } m > \sqrt{m^2 - 4\phi k \gamma} \iff \tilde{A} \frac{dm}{d\tilde{p}} < 0$$

and

$$\tilde{B} \geq 0 \quad \text{if } \frac{4\phi k \gamma}{2\sqrt{m^2 - 4\phi k \gamma}} \geq (m - \sqrt{m^2 - 4\phi k \gamma})$$

$$\frac{d\gamma}{d\tilde{p}} \geq 0 \iff \frac{\sigma_2^2}{\sigma_1^2} < \frac{R_1}{R_2}$$

Also,

$$\tilde{B} \geq 0 \iff \frac{k}{\sqrt{m^2 - 4\phi k \gamma}} \geq \tilde{L}^+$$

$$(b) \quad \tilde{L}^+ = \frac{\sqrt{4\phi k(\sigma_1^2 + \sigma_2^2)}}{2\phi\sigma_1^2} - \frac{m}{2\phi\sigma_1^2} = \bar{A} + \bar{B}$$

$$\frac{d\bar{A}}{d\tilde{p}} = \frac{\sqrt{4\phi k(\sigma_1^2 + \sigma_2^2)}}{2\phi\sigma_1^2} \left[ \frac{4\phi k}{2\sqrt{4\phi kV}} \left( \frac{d\sigma_1^2}{d\tilde{p}} + \frac{d\sigma_2^2}{d\tilde{p}} \right) - \frac{1}{\sigma_1^2} \frac{d\sigma_1^2}{d\tilde{p}} \right]$$

$$\frac{d\bar{B}}{d\tilde{p}} = -\frac{m}{2\phi\sigma_1^2} \left[ \frac{1}{m} \frac{dm}{d\tilde{p}} - \frac{1}{\sigma_1^2} \frac{d\sigma_1^2}{d\tilde{p}} \right]$$

$$\therefore \frac{d\tilde{L}^+}{d\tilde{p}} = \frac{1}{2\phi\sigma_1^2} \left[ 2\phi k\sigma_1^2 R_1 + 2\phi k\sigma_2^2 R_2 + (m - \sqrt{4\phi k(\sigma_1^2 + \sigma_2^2)}) R_1 - \frac{d\sigma_2^2}{d\tilde{p}} \right]$$

$$R_1 < 0, R_2 < 0, (m - \sqrt{4\phi k(\sigma_1^2 + \sigma_2^2)}) > 0 \text{ since } \tilde{L}^+ > 0$$

$$\therefore \frac{d\tilde{L}^+}{d\tilde{p}} < 0$$

□

